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FINAL REPORT ON THE CONCENTRATION OF TALLY POND MASSIVE SULPHIDE ORES FROM BUCHANS AREA, NEWFOUNDLAND

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FINAL REPORT ON THE CONCENTRATION OF TALLY POND MASSIVE SULPHIDE ORE FROM BUCHANS AREA, NEWFOUNDLAND

by

A.I. Stemerowicz* and G.W. Leigh**

ABSTRACT

A total of 44 selective flotation tests were carried out on 4 diamond-drill core samples from the various zones of the Tally Pond massive sulphide ore deposit. The use of sulphur dioxide in the pH range 4.5-5 as a sphalerite depressant in conjunction with aerative conditioning and the employment of the selective copper collector Aerofloat 238 was found to be the most effective copper selective flotation method for the North Zone ore (Sample No. 2). The best results achieved using this method at a primary grind of 80% minus 33 µm and with regrinding of copper and zinc rougher concentrates prior to cleaning were as follows:

Best Results Achieved for the North Zone No. 2 Sample

Product	Wt %	Analysis			Distribution %		
		Cu %	Zn %	Ag g/t	Cu	Zn	Ag
Copper conc	19.00	26.00	1.10	77.5	90.0	6.5	41.1
Zinc conc	4.35	2.38	50.89	66.9	1.9	69.2	8.1
Copper + zinc cl tail	9.60	-	-	-	3.2	17.8	15.9
Final tail	67.05	0.40	0.31	18.6	4.9	6.5	34.9
Feed (calcd)	100.00	5.49	3.20	35.8	100.0	100.0	100.0
Feed (assay)		5.27	3.35	34.9			

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The above copper results are judged to be close to the optimum that can be achieved for the North Zone sample. Despite the low iron content of the sphalerite in the North Zone ore (only 2.4%) it was not possible to produce a high grade zinc concentrate. The 50.9% zinc concentrate grade given in the above table is equivalent to only a 79% zinc sulphide grade with chalcopyrite and pyrite making up most of the balance. It is believed that the contaminating minerals occur as fine middling particles with each other and with sphalerite.

On the Southeast and South Zone ore samples, not enough testing was carried out to establish the optimum primary grind or the most effective copper selective flotation method. Using the sulphur dioxide + aeration method at a grind of 80% minus 36 µm the following results were obtained for the two Southeast Zone ore samples tested:

Results Obtained Using SO_2+ Aeration Method on Southeast Zone Samples

No. 5 Sample

Product	Wt %	Analysis			Distribution %		
		Cu %	Zn %	Ag g/t	Cu	Zn	Ag
Copper conc	4.84	16.24	6.52	58.5	53.0	3.9	4.7
Zinc conc	10.16	0.29	59.86	46.6	2.0	74.6	7.9
Copper + zinc cl tail	26.76	-	-	-	34.8	16.2	54.6
Final tail	58.24	0.26	0.74	33.9	10.2	5.3	32.8
Feed (calcd)	100.00	1.48	8.15	60.2	100.0	100.0	100.0
Feed (assay)		1.52	8.55	54.9			

No. 6 Sample

Copper conc	8.97	21.30	1.42	103.1	74.4	3.8	19.9
Zinc conc	4.62	0.39	49.60	35.7	0.7	68.0	3.5
Copper + zinc cl tail	25.81	-	-	-	20.2	23.7	56.5
Final tail	60.60	0.20	0.25	15.4	4.7	4.5	20.1
Feed (calcd)	100.00	2.57	3.37	46.5	100.00	100.0	100.0
Feed (assay)		2.69	3.83	45.1			

Only two tests were carried out on the South Zone No. 8 Sample. Copper/zinc selectivity could not be achieved by using sulphur dioxide as a sphalerite depressant. This was attributed to the supergene alteration of the sphalerite in the form of covellite-digenite rims and veinlets.

Except for a test on high-zinc copper concentrate produced from the Southeast Zone No. 5 Sample (Test B-1), copper-zinc separation of various products using the sulphur dioxide-hot pulp method to depress sphalerite was ineffective.

Keywords: flotation, selective, sulphides, complex, copper-zinc, Newfoundland

RAPPORT FINAL SUR LA CONCENTRATION DU MINERAI SULFURÉ MASSIF DE L'ÉTANG TALLY DANS LA RÉGION DE BUCHANS (TERRE-NEUVE)

par

A.I. Stemerowicz* and G.W. Leigh**

RÉSUMÉ

Nous avons effectué au total 44 essais de flottation sélective sur quatre échantillons prélevés par carottage au diamant dans diverses zones du gisement de minerai sulfuré massif de l'étang Tally. L'utilisation de dioxyde de soufre dans la plage de pH de 4,5 - 5 comme déprimant de la sphalérite, accompagnée d'un conditionnement par aération, et l'emploi du collecteur sélectif du cuivre Aerofloat 238 constituaient, a-t-on constaté, la méthode la plus efficace de flottation sélective du cuivre pour le minerai de la zone nord (échantillon n^{o} 2). Voici les meilleurs résultats qui ont été obtenus en utilisant cette méthode avec un produit dont 80% avait été réduit par broyage primaire à une granulométrie < 33 µm et en rebroyant les concentrés de dégrossissage du minerai de cuivre et de zinc avant de procéder à l'épuration:

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Meilleurs résultats obtenus avec l'échantillon n^{o} 2 de la zone nord

Produit	% en pds	Composition			% de distribution		
		Cu%	Zn%	Ag(g/t)	Cu	Zn	Ag
Concentré de cuivre	19.00	26.00	1.10	77.5	90.0	6.5	41.1
Concentré de zinc	4.35	2.38	50.89	66.9	1.9	69.2	8.1
Résidus de col. du cuivre et du zinc	9.60	-	-	-	3.2	17.8	15.9
Résidu final	67.05	0.40	0.31	18.6	4.9	6.5	34.9
Charge (calculée)	100.00	5.49	3.20	35.8	100.0	100.0	100.0
Charge (analysée)		5.27	3.35	34.9			

Les résultats données ci-dessus pour le cuivre sont proches, estime-t-on, de la valeur optimale qui est possible d'obtenir pour l'échantillon de la zone nord. Malgré la faible teneur en fer de la sphalérite dans le minerai de la zone nord (seulement 2,4%), il n'a pas été possible de produire un concentré de zinc de bonne qualité. Le concentré de zinc à 50,9% mentionné dans le tableau ci-dessus équivaut à une qualité correspondant seulement à du sulfure de zinc à 79%, le reste étant surtout constitué de chalcopyrite et de pyrite. Les minéraux qui constituent les espèces contaminantes se présentent sous forme de fines particules mixtes mélangées entre elles ou à de la sphalérite.

Dans le cas des échantillons de minerai provenant de la zone sud-est et sud, les essais effectués n'étaient pas suffisants pour déterminer la granulométrie optimale du broyage primaire ou la méthode la plus efficace de flottation sélective du minerai de cuivre. Grâce à la méthode faisant appel au dioxyde de soufre + aération et utilisant un produit dont 80% avait été réduit par broyage primaire à une granulométrie < 36 µm, on a obtenu les résultats suivants pour les deux échantillons de minerai de la zone sud-est qui avaient été soumis au essais:

Résultats obtenus avec la méthode au SO_2 + aération sur les échantillons de la zone sud-est

Échantillon n° 5

Produit	% en pds	Composition			% de distribution		
		Cu %	Zn %	Ag(g/t)	Cu	Zn	Ag
Concentré de cuivre	4.84	16.24	6.52	58.5	53.0	3.9	4.7
Concentré de zinc	10.16	0.29	59.86	46.6	2.0	74.6	7.9
Résidus de col. du cuivre et du zinc	26.76	-	-	-	34.8	16.2	54.6
Résidu final	58.24	0.26	0.74	33.9	10.2	5.3	32.8
Charge (calculée)	100.00	1.48	8.15	60.2	100.0	100.0	100.0
Charge (analysée)		1.52	8.55	54.9			

Échantillon n° 6

Concentré de cuivre	8.97	21.30	1.42	103.1	74.4	3.8	19.9
Concentré de zinc	4.62	0.39	49.60	35.7	0.7	68.0	3.5
Résidus de col. du cuivre et du zinc	25.81	-	-	-	20.2	23.7	56.5
Résidu final	60.60	0.20	0.25	15.4	4.7	4.5	20.1
Charge (calculée)	100.00	2.57	3.37	46.5	100.00	100.0	100.0
Charge (analysée)		2.69	3.83	45.1			

Seul deux essais ont été effectués sur l'échantillon n° 8 de la zone sud. Il n'a pas été possible d'obtenir une sélectivité cuivre/zinc en utilisant du dioxyde de soufre comme déprimant de la sphalérite, en raison de l'altération supergène de la sphalérite qui prenait la forme d'auréoles et de veinules de covellite-digénite.

Exception faite de l'essai sur un concentré de cuivre riche en zinc produit à partir de l'échantillon n^{o} 5 de la zone sud-est (essai B-1), la séparation du cuivre et du zinc dans divers produits à l'aide de la méthode au dioxyde de soufre - pulpe chaude pour déprimer la sphalérite n'était pas efficace.

Mots clés: flottation, sélectif, sulfures, complexe, cuivre-zinc, Terre-Neuve

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INTRODUCTION

Location of Deposit

The Tally Pond massive sulphide deposit is located in central Newfoundland about 35 km Southeast of Buchans. It consists of three zones designated the North, South, and Southeast Zones. The North zone accounts for about 75% of the ore reserves.

Mineralogy

A comprehensive mineralogical examination of the ore has been carried out by J.L. Jambor, Mineralogy Section, Mineral Processing Laboratory (1). It was concluded that: "Liberation of the chalcopyrite and sphalerite in the North Zone sulphides should be at economically satisfactory levels, and excellent liberation is projected for the Southeast Zone sulphides". The South Zone has been estimated to contain only 50-60000 tons ore. It has been subjected to supergene alteration which is evident from covellite-digenite rims and veinlets which have attacked not only chalcopyrite but also sphalerite. Therefore it is anticipated that selective flotation would be ineffective on this ore.

An unusual feature of the deposit was the occurrence of silver as hessite (Ag_2Te) the flotation characteristics of which are not known.

Ore Samples

The ore samples consisted of 17 boxes of split diamond-drill core received from J.L. Jambor. The core came from 6 holes which were specifically drilled to provide samples for metallurgical bench tests. Eight test samples were prepared from the core according to the instructions given by Jambor and Carson (2). Sample weights obtained are given in Table 1.

Table 1. Sample weights

Zone	Sample No.	Weight, kg
North	1	44.3
	2	76.9
	3	28.9
	4	16.7
Southeast	5	17.4
	6	21.9
South	7	24.3
	8	22.8

Object of Investigation

The object of the investigation was to develop a selective flotation method for the production of marketable grades of copper and zinc concentrates from the various ores.

Because it represents the bulk of the ore reserves the North Zone ore (No. 2 Sample was chosen as the ore to be tested initially. This was followed by testwork on the Southeast Zone ore (Samples No.5 and No. 6) and the South Zone ore (Sample No. 8). Samples No. 1,3 and 4 from the North Zone ore and Sample No. 7 from the South Zone ore were not tested.

Sampling and Analysis

The various ore samples consisting of diamond-drill core fragments were crushed in stages to minus 10 mesh (1680 µm). The minus 10 mesh material was then divided into 20 equal portions using a carrousel-type divider. One of these portions was chosen at random as a head sample while the remaining portions were combined and/or the weights adjusted to provide 2000-gram test charges. To minimize oxidation; crushed samples were stored in a freezer prior to being tested and the individual ore samples were not crushed until they were required for testwork. Head analyses of the 4 samples tested are given in Table 2.

Table 2. Head sample analyses*

Sample	Cu %	Zn %	Pb %	Fe %	S %	Insol %	Ag ppm	Au ppm
North Zone No. 2	5.27	3.35	0.29	38.00	42.05	4.34	34.9	0.37
Southeast Zone No. 5	1.52	8.55	1.25	30.66	38.98	12.16	59.9	-
Southeast Zone No. 6	2.69	3.83	0.64	24.88	30.56	25.68	45.1	-
South Zone No. 8	3.24	5.42	0.99	38.60	47.65	1.59	56.7	-

* by MSL Chemical Laboratory

A 100-g portion of the minus 10 mesh North Zone, No. 2 head sample was also submitted to the Mineralogy Section for the determination of the liberation characteristics of the minerals.

OUTLINE OF INVESTIGATION

Scope

A total of 44 flotation tests was carried out on samples from the various ore zones as follows:

North Zone	No. 2 Sample -	30, Prefix "A"
Southeast Zone	No. 5 Sample -	8, Prefix "B"
Southeast Zone	No. 6 Sample -	4, Prefix "C"
South Zone	No. 8 Sample -	2, Prefix "D"

The object in most tests was to selectively float a copper concentrate from the ground ore followed by activation and flotation of the sphalerite. Copper-zinc separation using the sulphur dioxide method was also tried in several tests on bulk copper-zinc concentrates and other products. Because of the low lead content of the North Zone No. 2 Sample (0.29%) in relation to that of the other metals production of a lead concentrate was not feasible. On the higher-lead ore samples from the other two zones only one attempt was made to produce a lead concentrate by sequential copper-lead-zinc selective flotation (Test B-2).

Grinding

To ensure mineral liberation very fine grinding in the range 80% passing 24 to 45 µm was employed in all tests. The optimum grind was determined only for the North Zone, No. 2 Sample ("A" series).

Copper Flotation

Four selective flotation techniques were tried for the flotation of chalcopyrite from pyrite and sphalerite. These involved the use of various combinations of depressants and pH's as follows:

(1) sulphur dioxide, pH 5
(2) high lime, pH 11+
(3) high lime + sodium cyanide, pH 11+
(4) soda ash + sodium cyanide, pH 9-9.5

All of the above reagents were added to the grind except sulphur dioxide which was added to a conditioning step prior to copper flotation. In most tests a 30-minute period of aerative conditioning in a lab aerator was employed prior to copper flotation. Simple conditioning in a lab flotation cell with the air cock turned off was also tried in conjunction with the first three depressant-pH combinations given above.

A combination of Aerofloat 238 and amyl xanthate was used as copper collector. Standard practice was to add all of the xanthate and about ½ of the Aerofloat 238 to the conditioning step - the balance was added in stages to the copper rougher. In 2 tests alternative copper collectors were tried - Aerophine 3418A in place of xanthate in test A-18 and Aerofloat 249 as the sole copper collector in Test A-19.

Both Southeast Zone Ore Samples Nos. 5 and 6 contained graphite. This naturally floating mineral has an adverse effect on selective copper flotation. Some of the Depramin series of reagents (carboxymethyl-celluloses) and humic acid were tried as graphite depressants. Also in one test (B-3) a graphite concentrate was floated off with frother prior to the selective copper flotation step.

The copper rougher concentrate was cleaned with and without prior regrinding. The other important cleaning variable investigated was the use of specific depressants: lime to depress pyrite and sulphur dioxide to depress sphalerite.

Zinc Flotation

To ensure optimum selectivity 1000 g/t copper sulphate was added for sphalerite activation along with lime addition to give a pH of 11.5-12. For the North Zone No. 2 Sample this amount of copper sulphate is probably much higher than warranted by the 3.35% zinc in the heads; therefore zinc flotation was also tried with lower levels of copper sulphate addition (500 and 250 g/t). Sodium Aerofloat was used as the principal zinc collector augmented by the addition of small amounts of amyl xanthate. For optimum results the zinc rougher concentrate was reground prior to cleaning. Pyrite, which was the main contaminant in the zinc rougher concentrate, was depressed by lime additions to maintain a pH of 11+ in all zinc cleaning stages.

Copper-Zinc Separation

Copper-zinc separation using sulphur dioxide in a heated pulp as the sphalerite depressant was tried either as an alternative or adjunct to sequential copper-zinc selective flotation on the following test products:

(1) Zinc rougher concentrate (Test A-5)
(2) Zinc cleaner concentrate (Test A-4)
(3) Bulk copper-zinc cleaner concentrate (Test A-24, D-2)
(4) High zinc copper concentrate (Test B-1)

Mineralogical and Image Analysis Study

A mineralogical and image analysis study was conducted by the Mineralogy Section on all of the products from test A-10(2). The objective was to determine the proportion of free and composite mineral particles in various particle size fractions ranging from about minus 1 to minus 52 µm.

Selective Flotation Evaluation Criteria

Separation efficiency as defined by Schultz(3) is used as the measure of the degree of selectivity achieved between chalcopyrite and sphalerite and chalcopyrite and pyrite during the copper flotation step. It is obtained by subtracting the percent zinc or pyrite recovered in the copper concentrate from the percent copper recovery in the copper concentrate.

Progess Report

A progress report(4) was issued to report results of Tests A-1 to A-11 carried out on the North Zone No. 2 sample during the period February 27 to April 30, 1985.

DISCUSSION AND EVALUATION OF RESULTS OF NORTH ZONE NO. 2 SAMPLE

Best Results

The best results on the North Zone ore sample were achieved in Test A-29 using the sulphur dioxide + aeration copper selective flotation method

at a primary grind of 80% minus 33 µm. Results of Test A-29 are shown below in Table 3 while flowsheet, details of test procedure and comprehensive metallurgical balance are given in the Appendix. Also in the Appendix are Tables A-1 and A-2 which summarize test procedure and results for all the tests in this series.

Table 3. Best flotation results achieved for the North Zone, No. 2 Sample using SO_2+ aeration at a primary grind of 80% - 33 µm (Test A-29)

Product	Wt %	Cu %	Zn %	Pb %	Fe %	S %	Insol %	Ag ppm	Au ppm	Sep eff., % Cu/Zn
Copper cl conc - 3	19.00	26.00	1.10	0.50	77.5	90.0	6.5	37.2	41.1	83.5
Copper cl tail - 3	2.69	4.00	2.49	0.91	79.4	2.0	2.1	9.6	6.0	
Zinc conc	4.35	2.38	50.89	0.40	66.9	1.9	69.2	6.8	8.1	
Zinc cl tails-comb	6.91	0.99	7.25	0.26	51.5	1.2	15.7	7.0	9.9	
Final tails	67.05	0.40	0.31	0.15	18.6	4.9	6.5	39.4	34.9	
Feed (calcd)	100.00	5.49	3.20	0.26	35.8	100.00	100.00	100.00	100.00	
Copper cl conc - 2 (calcd)	21.69	23.27	1.27	0.55	77.7	92.0	8.6	46.8	47.1	
Copper ro tail (calcd)*	78.31	0.56	3.73	0.17	24.2	80.0	91.4	53.2	52.9	83.4
Zin ro conc	11.26	1.53	24.11			3.1	84.9			

* Includes No. 1 and 2 copper cleaner tailings

In Test A-29 both copper and zinc rougher concentrates were reground prior to cleaning. Extent of regrinding was not determined but in other similar tests K_{80} for copper rougher concentrates before and after regrinding was 24-25 µm and 18-19 µm respectively. The zinc rougher concentrate was reground using the same procedure as that employed for the copper rougher concentrate except that the pebble charge was reduced from 6 to 3kg. Considering that the weight of zinc rougher concentrate was only about 1/3 that of the copper rougher concentrate this should have provided for an adequate amount of regrinding.

After regrinding, the copper rougher concentrate was cleaned twice with sulphur dioxide added to depress sphalerite. Sulphur dioxide is not a very effective depressant for pyrite. Therefore to obtain maximum grade the copper concentrate was cleaned a third time with lime at a pH of 11.8. This resulted in an increase in copper concentrate grade from 23.3 to 26.0% copper with only a 2% loss of copper to the cleaner tailing. The increase in concentrate grade was due almost entirely to the rejection of pyrite which decreased from a calculated value of 30.1% in the second copper cleaner concentrate to 22.6% in the third copper cleaner concentrate.

Instead of retaining the first and second copper cleaner tailings for assay as is the normal practice in batch testing, these products were combined, filtered and added to the copper rougher tailing prior to zinc flotation. The rationale for adopting this procedure was that it had been found in previous tests that high amounts of zinc were rejected to the cleaner tailings accompanied by the rejection of only a relatively small amount of copper. Test A-27, the results of which are given in Table 4, is a typical example. To obtain more meaningful zinc flotation results it was desirable to include the high-zinc copper cleaner tailings in the Test A-29 zinc flotation feed.

Table 4. Test A-27 copper flotation results

Product	Wt %	Analysis %		Distribution %	
		Cu	Zn	Cu	Zn
Copper conc	23.00	21.00	2.04	90.9	15.2
Copper cl tail - 2	4.91	2.76	4.80	2.6	7.7
Copper cl tail - 1	10.82	1.30	6.80	2.7	23.9
Copper ro tail	61.27	0.33	2.67	3.8	53.2
Feed (calcd)	100.00	5.31	3.08	100.0	100.0
Copper ro conc	38.73	13.18	3.72	96.2	46.8
Copper cl tail 1+2	15.73	1.76	6.18	5.3	31.6

In view of the complex, fine-grained nature of the North Zone ore, copper results obtained in Test A-29 can be characterized as being very good. Especially notable was the very high copper recovery in the copper concentrate. On the other hand zinc concentrate grade at 50.9% was unsatisfactorily low considering the fact that the iron content in the sphalerite was only 2.3%. The calculated mineralogical composition of this concentrate is as follows: sphalerite 79.0%, chalcopyrite 6.9%, galena 0.5%, balance 13.6% (mostly pyrite). The 35% loss of silver in the final tailing is not judged to be excessive when compared to other base metal sulphide ores containing a similar amount of silver.

Determination of Optimum Zinc Concentrate Grade

To determine the optimum zinc concentrate grade that could be produced from the ore Test A-30 was carried out using essentially the same zinc flotation procedure as Test A-29 except that the froth from the third stage zinc cleaner was collected in four separate increments. Instead of using this technique for producing high-grade zinc concentrates it would have been preferable to subject the third stage zinc cleaner concentrate to an additional two or three cleaning stages but this was not considered feasible because of an insufficient weight of concentrate (only 92 grams). Zinc cleaning results for test A-30 are given in Table 5.

Table 5. Zinc cleaning results - Test A-30

Product	Analysis %							Distribution %		
3rd stage Zn cl conc	Cu	Zn	Pb	Chalco	Sphal	galena	pyrite	Cu	Zn	Pb
Increment 1	3.52	52.34	1.18	10.2	81.3	1.4	7.1	17.0	25.5	15.3
Increment 1 and 2	3.62	52.12	1.23	10.5	80.9	1.4	7.2	30.3	43.9	27.6
Increment 1 to 3	3.78	50.76	1.33	10.9	78.8	1.5	8.8	48.0	64.9	45.2
Increment 1 to 4	3.89	49.68	1.39	11.3	77.1	1.6	10.0	59.9	77.2	57.6
2nd stage Zn cl conc	3.92	46.81	1.40	11.3	72.7	1.6	14.4	72.0	86.8	69.1
1st stage Zn cl conc	3.78	43.13	1.35	10.9	67.0	1.6	20.5	78.5	90.3	75.2
Zn rough conc	2.75	27.23	1.02	8.0	42.3	1.2	48.5	100.0	100.0	100.0

As can be seen the zinc concentrate in Test A-30 could not be upgraded to what could be considered a satisfactory grade - 55% zinc or higher. Chalcopyrite and pyrite were the major contaminants. In this test the copper concentrate was cleaned twice with lime at a pH of 11+ instead of sulphur dioxide which was employed in the first two copper cleaners in Test A-29. This resulted in a greater rejection of copper (probably in the form of chalcopyrite-pyrite middlings) and lead to the copper cleaner tailings. When the copper cleaner tailings were added to the zinc flotation feed most of the lead and copper were subsequently recovered in the third stage zinc cleaner concentrate (increments 1 to 4 combined) to give a chalcopyrite and galena content of 11.3% and 1.6% respectively as against 6.9% and 0.5% respectively for the equivalent product in Test A-29. Substituting the lower Test A-29 chalcopyrite and galena contents it is estimated that the Test A-30 third stage zinc cleaner concentrate grade would have been about 2.9% higher.

Copper-Zinc Separation

The results of the three tests in which copper-zinc separation was tried are given below as follows:

Table 6 - on zinc cleaner concentrate
Table 7 - on zinc rougher concentrate
Table 8 - on bulk copper-zinc cleaner concentrate

In each case the feed was conditioned for 10 minutes prior to flotation at a pulp temperature of about 80°C with sulphur dioxide added to give a pH in the range 4 to 4.5. The separation froth product is referred to as the "secondary copper concentrate" except in Table 8 where the separation froth product is the copper concentrate.

Very little copper/zinc selectivity was achieved in the first attempt at copper-zinc separation on the zinc cleaner concentrate (Table 6). Some improvement in selectivity was obtained in the succeeding test on the zinc rougher concentrate as indicated by the increase in separation efficiencies. It is believed that appreciably higher efficiencies would have been achieved had the zinc rougher concentrate been reground prior to

Table 6. Results of copper-zinc separation on zinc cleaner concentrate (Test A-4)

Product	Wt %	Analysis %		Distribution %		Sep eff., %
		Cu	Zn	Cu	Zn	
Sec Cu conc	36.17	3.58	38.24	47.1	33.5	13.6
Sec Cu cl tail	24.45	2.77	41.03	24.6	24.3	
Separation tail	39.38	1.98	44.30	28.3	42.2	
Feed (calcd)	100.00	2.75	41.31	100.0	100.0	

Table 7. Results of copper-zinc separation on zinc rougher concentrate (Test A-5)

Product	Wt %	Analysis %		Distribution %		Sep eff., %
		Cu	Zn	Cu	Zn	
Overall						
Primary Cu conc	21.12	20.30	1.86	81.0	13.1	67.9
Zn conc (sepn tail)	4.85	0.94	27.29	0.9	44.1	
Sec Cu conc	1.27	14.62	16.07	3.5	6.8	
Sec Cu Cl tail	2.75	3.89	28.47	2.0	26.0	
Final tail	70.01	0.95	0.43	12.6	10.0	
Feed (calcd)	100.00	5.27	3.00	100.0	100.0	
Combined Cu conc	22.39	19.98	2.67	84.5	19.9	64.6
Copper-Zinc Separation Rougher						
Sec Cu ro conc	45.38	7.28	24.55	86.6	42.8	43.8
Separation tail	54.62	0.94	27.29	13.4	57.2	
Feed (Zn ro conc)	100.00	3.82	26.05	100.0	100.0	
Copper-Zinc Separation Cleaner						
Sec Cu Cl conc	31.60	14.62	16.07	63.5	20.7	42.8
Sec Cu Cl tail	68.40	3.89	28.47	36.5	79.3	
Feed (Sec Cu ro conc)	100.00	7.28	24.55	100.0	100.0	

Table 8. Results of copper-zinc separation on bulk Cu-Zn cleaner concentrate (Test A-24)

Product	Wt %	Analysis %		Distribution %		Sep eff., %
		Cu	Zn	Cu	Zn	
Copper conc	88.19	24.65	2.50	96.8	27.8	69.60
Separation tail	11.81	6.00	48.43	3.2	72.2	
Feed (calcd)	100.00	22.45	7.92	100.0	100.0	

the separation step. In the test on the bulk copper-zinc cleaner concentrate (Table 8) the bulk rougher concentrate was reground prior to cleaning and separation. Note that although almost 97% of the copper was recovered in the froth product, the copper in the separation tailing (zinc concentrate) was not reduced to an acceptable level. This is due to the unfavourably high ratio of chalcopyrite to sphalerite in the separation feed (5.3:1). For this reason copper-zinc separation of a bulk copper-zinc concentrate cannot be considered a viable alternative to sequential copper-zinc selective flotation from the ore. It could best be utilized as an auxiliary step in reducing copper content in the zinc concentrate.

Optimum Primary Grind

As noted previously the fineness of the primary grind was varied at 4 levels from 80% minus 45 µm to 80% minus 24 µm. Table 9 gives the K_{80} obtained for the various grinding times in the lab rod mill.

Table 9. K_{80} obtained for 2000-gram charge of No. 2 Sample ground for various time periods at 65% solids in a 7 x 14 Denver lab rod mill with 20 kg of rods

Grinding time min	K_{80}, µm	
	By Sieve Analysis	By L & N Microtrac
30	55.6	61
45	41.2	45
60	-	39
75	-	33
120	-	24

Note that the K_{80} determined by sieve analysis is smaller than that determined by a Leeds and Northrop particle size analyser. This difference has been obtained for other complex sulphide ores and is due to the fact that the Microtrac particle size is an average of all dimensions whereas sieve particle size is determined by the smallest dimension which will pass through the sieve opening.

Table 10 gives a comparison of the copper and zinc tailing losses and rougher concentrate grades using the various primary grinds. In this comparison the possible effect of other test variables has not been considered.

Table 10. Tailing losses and rougher concentrate grades versus fineness of primary grind

Test No.	Primary grind K_{80} µm	% Cu		% Zn	
		Cu ro tail	Cu ro conc	Zn ro tail	Zn ro conc
A-2	45	1.60	18.78	0.29	30.23
A-3	45	1.30	20.05	0.14	16.35
A-4	45	1.31	*	0.35	30.20
A-5	45	1.27	*	0.43	26.05
A-6	39	0.88	18.61	0.14	17.73
A-7	33	0.66	19.09	0.13	17.41
A-8	24	0.37	13.11	0.20	23.70
A-9	33	0.29	12.85	**	
A-10	33	0.50	16.80	0.14	21.01
A-11	33	0.74	18.63	0.18	17.59

* Copper ro conc could not be calculated because copper cleaner tailings were diverted to zinc flotation

** Zinc flotation not carried out in this test

Taking into account the relationship between rougher concentrate grade and recovery it can be concluded that the grind required for optimum copper recovery is 80% minus 33 µm while for optimum zinc recovery it is a little coarser at 80% minus 39 µm.

Metal Losses in Tailings by Size Fractions

Samples of final tailings from Test A-7 (primary grind, 80% minus 33 µm) and Test A-8 (primary grind, 80% minus 24 µm) were cyclosized and the six cyclosizer fractions submitted for analysis. The object was to compare metal losses in the tailings by size fractions for these two levels of fineness of grind. This comparison is given in Table 11.

Table 11. Comparison of metal losses in final tailings by size fractions

Product	Diam µm*	Wt % retained	Cum Wt % passing	Analysis %		Distribution %	
				Cu	Zn	Cu	Zn
Test A-7 final tailings, primary grind 80% -33 µm							
Cone 1 u'flow	25.7	18.5	81.5	0.40	0.12	26.1	15.3
Cone 2 u'flow	19.6	35.2	46.3	0.29	0.12	36.0	29.1
Cone 3 u'flow	14.3	11.4	34.9	0.18	0.11	7.2	8.6
Cone 4 u'flow	9.8	9.8	25.1	0.17	0.11	5.9	7.5
Cone 5 u'flow	7.5	5.6	19.5	0.17	0.12	3.4	4.6
Cone 5 u'flow	-7.5	19.5		0.31	0.26	21.4	34.9
Feed (calcd) Feed (assay)		100.0		0.29 0.29	0.15 0.13	100.0	100.0
Test A-8 final tailings, primary grind 80% -24 µm							
Cone 1 u'flow	25.7	10.3	89.7	0.22	0.12	7.6	6.2
Cone 2 u'flow	19.6	26.1	63.6	0.20	0.11	17.4	14.3
Cone 3 u'flow	14.3	15.7	47.9	0.20	0.12	10.5	9.4
Cone 4 u'flow	9.8	13.8	34.1	0.17	0.12	7.8	8.3
Cone 5 u'flow	7.5	7.6	26.5	0.18	0.13	4.6	4.9
Cone 5 u'flow	-7.5	26.5		0.59	0.43	52.1	56.9
Feed (calcd) Feed (assay)		100.0		0.30 0.32	0.20 0.20	100.0	100.0

* Calculated using SG of 4.33

In the case of copper it can be deduced from the high losses sustained in the two coarsest fractions of the Test A-7 tailings that complete liberation of chalcopyrite had not been achieved at a grind of 80% minus 33 µm. At the grind of 80% minus 24 µm employed in Test A-8 the copper losses in the two coarsest fractions were greatly reduced but this was offset by a much greater loss in the finest fraction with the result that the overall copper loss was similar to that sustained at the coarser grind.

For zinc it can be concluded from the consistently low zinc values in all fractions except the finest that liberation of the sphalerite had been achieved at a grind of 80% minus 33 µm (Test A-7). Further grinding to 80% minus 24 µm (Test A-8) resulted in a greater loss of zinc to the finest fraction which accounts for the increase in zinc content in the tailing from 0.15% in Test A-7 to 0.20% in Test A-8. It should be pointed out here that reagent usage has not been considered in the above evaluation of tailing losses. It is possible that the cyanide employed in Test A-8 may have had some effect on both copper and zinc tailing losses in the finest fraction.

EFFECTIVENESS OF THE VARIOUS COPPER SELECTIVE FLOTATION

Methods Tested

In the first series of tests (A-1 to A-11) reported in the progress report it was found that the soda ash + NaCN + aeration method gave: (1) the best copper-zinc selectivity and (2) the best zinc concentrate grade-recovery combination while the employment of the high lime + aeration method resulted in better selectivity against pyrite but this was accompanied by poor selectivity against sphalerite. Results are summarized in Table 12.

The lower copper recovery obtained in Test A-5 is attributed to the coarser grind employed. It should also be pointed out that at this stage of the investigation regrinding of rougher concentrates prior to cleaning has as yet not been tried.

The sulphur dioxide method, which eventually gave the best results when used in conjunction with aerative conditioning, was initially tried in Test A-1. In this test the pulp was conditioned in the laboratory flotation cell with the air cock turned off and with sulphur dioxide added to give a pH of 5.5. Results are given in Table 13.

Table 12. Summary of best results for first series of tests (A1-A-11)

Test No.	Copper selective flotation method	Grind K_{80} µm	Remarks	Conc grade, %			Recovery %			Sep eff., %	
				Cu	Zn	Py	Cu	Zn	Py	Cu/Zn	Cu/Py
A-5	Soda ash + NaCN + aeration	45	Best Cu/Zn separation efficiency	20.30	1.86	37.5	81.0	13.1	9.9	67.9	71.1
A-10	High lime + aeration	33	Best Cu conc grade-recovery combination	20.58	5.11	32.2	90.5	36.9	9.3	53.6	81.2
A-4	Soda ash + NaCN + aeration	45	Best Zn conc grade-recovery combination	2.75	41.31	-	2.7	75.5		-	-

Table 13. Results of initial test using sulphur dioxide (Test A-1)

Product	Wt %	Analysis %		Distribution %		Sep eff., %
		Cu	Zn	Cu	Zn	
Copper conc	7.16	27.22	0.56	37.9	1.3	36.6
Copper cl tail 2	1.83	10.99	1.62	3.9	0.9	
Copper cl tail 1	7.10	10.09	1.52	13.9	3.4	
Zinc ro conc	7.89	0.69	9.83	24.4	1.1	
Final tail	76.02	2.9	2.9	69.9	43.3	
Feed (calcd)	100.00	5.15	3.17	100.0	100.0	
Copper ro conc (calcd)	16.09	17.82	1.10	55.7	5.6	50.1

The sulphur dioxide method gave excellent copper-zinc selectivity but at the expense of much lower copper recovery. The net result was lower Cu/Zn separation efficiency when compared to some of the other selective copper flotation methods employed in the first series of tests. Sulphur dioxide also had an adverse effect on zinc flotation. As can be seen, only about 24% of the zinc was recovered in a rougher concentrate which assayed only 9.83% zinc and appeared to be mostly composed of pyrite. The authors have observed the same adverse effect on other copper-zinc ores and

attribute it to the fact that the sulphite ion interferes with copper activation of the sphalerite by reducing the cupric ion concentration in the pulp (5).

Reproducibility of Copper Flotation Results

The last of the first series of Tests (A-11) was carried out on May 1, 1985. Testing was resumed with Test A-12 on August 19, 1985 on identical material, i.e. on a 2000-gram lot of minus 10 mesh ore from the first half of the North Zone No. 2 sample. The object of Test A-12 was to repeat Test A-5 procedure (soda ash + NaCN + aeration) but at a finer primary grind of 80% minus 33 µm and with regrinding of the copper rougher concentrate prior to cleaning. Because the time interval between Test A-5 and A-12 was about 5 months some deterioration in selectivity due to oxidation effects could be expected. A comparison of results did not indicate any evidence of this although copper recovery was lower than anticipated (83.7% versus 90%). However, when the Test A-12 procedure was repeated in Test A-17 on the newly-crushed third quarter of the No. 2 sample which had been stored at ambient temperatures for about 7 months at the minus ½-inch size, there was a severe deterioration in copper-zinc selectivity. Much greater differences in results were obtained when the high lime + NaCN method was employed. Results of repeat tests employing the two copper selective flotation methods are compared in Table 14.

Note the very large difference in copper flotation results between Tests A-16 and A-21 despite the fact that they were conducted on the same material (third quarter of No. 2 sample) and within about 2 weeks of each other. In Test A-16 the copper/zinc selectivity achieved can be considered to be at an acceptable level while in Test a-21 it has deteriorated to the point where bulk copper-zinc flotation was obtained. In another test using the same method (see Test A-23, Table B-1) an increase in cyanide addition to 250 g/t resulted in only a marginal decrease in zinc recovered in the copper cleaner concentrate to about 91% to give a copper/zinc separation efficiency of 4.2% versus the -3.0% obtained in Test A-21. No explanation can be given for the large difference in copper flotation results between Tests A-16 and A-21 other than a possible mix-up in samples i.e. Test A-16 had mistakenly had been conducted on the first half sample instead of the third quarter sample. In any case the copper selective flotation methods carried out at an alkaline pH with cyanide as zinc depressant had to be abandoned because they were no longer effective.

Table 14. Comparison of copper flotation results for repeat tests on North Zone No. 2 Sample

Test No.	Date 1985	Sple	Wt %	Copper flotation results							
				Analysis %			Distribution %			Sepn eff., %	
				Cu	Zn	Pyrite	Cu	Zn	Pyrite	Cu/Zn	Cu/Py
Soda ash + 125 g/t NaCN + aeration											
A-5	Mar. 13	1st ½	*C-21.12	20.20	1.86	37.5	81.0	13.1	9.9	67.9	71.1
A-12	Aug. 19	1st ½	C-20.49	21.06	1.71	35.4	83.7	11.8	9.1	71.9	74.6
			R-41.82	11.24	1.93	63.9	91.2	27.2	33.4	64.0	57.8
A-17	Sept. 24	3rd ¼	C-32.57	14.37	6.30	48.0	87.4	67.7	19.7	19.7	67.7
			R-41.82	7.83	3.71	71.2	94.4	74.0	58.0	20.4	36.4
High lime + 125 g/t NaCN - conditioned in cell without air											
A-16	Sept. 23	3rd ¼	C-18.69	24.30	2.70	25.3	85.8	15.9	5.9	69.9	82.9
			R-39.47	12.99	2.92	57.5	96.9	36.3	28.6	60.6	68.3
A-21	Oct. 9	3rd ¼	C-33.61	15.90	9.60	37.6	94.7	97.7	16.1	-3.0	78.6
			R-45.03	12.23	7.23	46.8	97.3	98.7	30.4	-1.4	64.9
A-26	Nov. 18	4th ¼	C-22.75	18.72	8.48	32.4	95.2	71.7	11.1	23.5	83.8
			40.01	13.02	6.26	52.2	97.2	79.7	26.4	17.5	70.8

* C - Copper cleaner concentrate
R - Copper rougher concentrate

Sulphur Dioxide Method

The only viable alternative was to go back to the sulphur dioxide method which had been tried in the first series of tests (Test A-1) but was found wanting because it had such a deleterious effect on zinc flotation. When it was again tried in Test A-25 very poor copper/pyrite selectivity was obtained accompanied by the evolution of hydrogen sulphide gas from the pulp. It was found that the evolution of hydrogen sulphide could be prevented by intensely aerating the ground pulp prior to the addition of the sulphur dioxide. The aeration step also resulted in a dramatic improvement in copper/pyrite selectivity (Test A-27). Results of these initial tests using sulphur dioxide are compared in Table 15.

Table 15. Comparison of results of initial tests using sulphur dioxide for selective copper flotation

Test No.	Product	Wt %	Analysis %			Distribution %			Sepn eff., %	
			Cu	Zn	Pyrite	Cu	Zn	Pyrite	Cu/Zn	Cu/Py
A-1	Cu cl conc - 2	7.16	27.22	0.56	20.1	37.9	1.3	1.8	36.6	36.1
	Cu cl conc - 1	8.99	23.92	0.78	29.3	41.8	2.2	3.3	39.6	38.5
	Cu ro conc	16.09	17.82	1.10	46.4	55.7	5.6	9.4	50.1	46.3
A-25	Cu cl conc	49.37	8.88	1.12	72.2	82.6	16.9	45.0	65.9	37.6
	Cu ro conc	69.42	7.03	1.62	76.8	91.9	34.3	69.3	57.6	22.6
A-26	Cu cl conc - 2	23.00	21.00	2.04	35.3	91.0	15.2	10.2	75.8	80.8
	Cu cl conc - 1	27.91	17.79	2.53	43.9	93.5	22.9	15.4	70.6	78.1
	Cu ro conc	38.73	13.18	3.72	55.5	96.2	46.8	27.0	49.4	69.2

Notes:

(1) Primary grind A-1, 80% -45 µm, A-25 and A-27, 80% -33 µm

(2) Test A-1 and A-25 - pulp conditioned with sulphur dioxide in cell with air cock turned off, Test A-27 pulp conditioned in aerator for 30 minutes prior to the addition of sulphur dioxide

(3) Rougher concentrates not reground prior to cleaning

(4) Feed to Test A-1 - first half or sample, feed to tests A-25 and A-27 - 4th quarter of sample

Zinc flotation was not carried out in Test A-25 but in Test A-27 no particular difficulty was encountered in floating off a zinc concentrate after copper flotation as had been the case in Test A-1. It should also be pointed out that the level of selectivity obtained for copper rougher flotation in Test A-27 was in no way superior to that obtained using the other methods as Table 16 will illustrate.

Table 16. Comparison of copper rougher flotation results - sulphur dioxide versus the other methods

Test No.	Selective Flotation Method	Copper Rougher Concentrate								
		Wt %	Analysis %			Distribution %			Sepn eff., %	
			Cu	Zn	Pyrite	Cu	Zn	Pyrite	Cu/Zn	Cu/Py
A-27	Sulphur dioxide + aeration	38.73	13.18	3.72	55.5	96.2	46.8	27.0	49.4	69.2
A-12	Soda ash + NaCN + aeration	41.82	11.24	1.93	63.9	91.2	27.2	33.4	64.0	57.8
A-16	High lime + NaCN - condit. without air	39.47	12.99	2.92	57.5	96.9	36.3	28.6	60.6	68.3

Zinc Flotation

In the first series of tests (A-1 to A-11) the copper rougher tailing was subjected to zinc flotation in every test except A-9. In the final test series (A-12 to A-30) the authors were preoccupied with the copper/zinc selectivity problem which had to be resolved before attempting zinc flotation. Consequently zinc flotation was carried out only in the last four tests (A-27 to A-30). With one exception (Test A-1) zinc recoveries obtained for zinc rougher flotation from the copper rougher tailings were in the 90% + range (see Table B-2). In Test A-1 the use of sulphur dioxide in the preceding copper flotation step had an adverse effect on zinc flotation. However this did not occur in Test A-27 and subsequent tests in which the pulp was aerated prior to the addition to sulphur dioxide.

In those tests in which copper cleaner tailings were diverted to zinc flotation (A-4, A-5, A-28, A-29, A-30) zinc tailings losses were appreciably higher indicating that some of the zinc rejected to the copper cleaner tailings may have been in the form of pyrite-sphalerite middling particles which did not float under the selective conditions prevailing in zinc rougher flotation.

The amount of copper sulphate employed (250, 500, 1000 and 1500 g/t) did not have any pronounced effect on zinc results. The only effect noted was that higher copper sulphate additions resulted in a more stable, gummy froth. In every test except A-29 the copper rougher tailing was conditioned with copper sulphate and lime in the lab flotation cell for 10 minutes with the air cock turned off. In Test A-29 the copper rougher tailing was transferred to the lab aerator and aerated for 30 minutes with 1000 g/t copper sulphate and lime for a pH of 11.9. When the pulp was transferred back to the flotation cell it was noted that the froth was barren indicating that the sphalerite had not been activated. It was therefore necessary to add an additional 1000 g/t copper sulphate and condition for a further 10 minute period before there was any visual evidence that the sphalerite had been activated.

Compared to other sulphide ores the authors have investigated sphalerite/pyrite selectivity in zinc rougher flotation was poor. Zinc rougher concentrate grades ranges from about 16.4 to 31.4% zinc. However no difficulty was encountered in rejecting pyrite in the subsequent cleaning steps. The maximum zinc concentrate grade that could be achieved without prior regrinding of the rougher concentrate was about 42% zinc-with regrinding this increased to about 51% zinc. Since the pure sphalerite in the ore is estimated to have a zinc content of 64.4% there is much scope for improving zinc concentrate grade providing additional mineral liberation can be achieved by further regrinding. The most promising technique would be to regrind the final zinc concentrate and then subject it to copper-zinc separation using the sulphur dioxide method. The cleaned froth product which should consist mostly of chalcopyrite and pyrite can be recycled to copper flotation feed. Regrinding the first and second copper cleaner tailings before recycling these products to zinc flotation feed may also prove to be beneficial.

Results of Mineralogical and Image Analysis Study

From the mineralogical and image analysis studies conducted on the minus 10 mesh North Zone No. 2 sample and the flotation test products from Test A-10 (see Table 17) the following results were obtained:

(1) Optimum grind to liberate chalcopyrite and sphalerite was determined to be 80% minus 37µm.

(2) Chalcopyrite and sphalerite recoveries were high - 98% of the free chalcopyrite and 72% of the unliberated chalcopyrite were recovered in the copper concentrate while 98% of the free sphalerite and 77% of the unliberated sphalerite were recovered from the copper rougher tailings.

(3) A high proportion (63%) of the zinc in the copper concentrate which contained 7.9% sphalerite (5.11% Zn) was in the form of free sphalerite particles ranging in size from 2.3 to 26 µm.

(4) The main contaminant in the zinc concentrate (29.67% Zn) was pyrite. About 2/3 of this pyrite (46% weight of concentrate) consisted of free grains while the balance was in the form of middling particles with other minerals.

Table 17. Results for Test A-10 (high lime + aeration)

Product	Wt %	Analysis %			Distribution %			Sepn eff., %	
		Cu	Zn	Pyrite	Cu	Zn	Pyrite	Cu/Zn	Cu/Py
Copper conc	22.93	20.58	5.11	32.2	90.5	36.9	9.3	53.6	81.2
Copper cl tail - 1	1.13	3.50	4.26		0.8	1.5			
Copper cl tail - 2	4.84	2.02	2.13		1.9	3.2			
Zinc conc	5.81	1.94	29.67		2.2	54.3			
Zinc cl tail	2.60	1.71	1.65		0.8	1.3			
Final tails	62.69	0.32	0.14		3.8	2.8			
Feed (calcd)	100.00	5.21	3.18		100.0	100.0			

It should be pointed out that in Test 10 the employment of the high lime + aeration method resulted in high copper recovery but poor copper/zinc selectivity. Much better selectivity was achieved using the soda ash + NaCN + aeration method (e.g. Test A-5). Also the zinc rougher concentrate in Test A-10 was not cleaned up to the optimum grade attainable without regrinding which was 41-42% zinc. The submission of the Test A-10 products for mineralogy was not the best choice but it was the only test available at that point in the investigation for which there was a complete set of test products.

DISCUSSION AND EVALUATION OF RESULTS FOR SOUTHEAST ZONE SAMPLES NO. 5 AND 6

Sulphur Dioxide + Aeration Method

The sulphur dioxide + aeration method for selective copper flotation was tried on Southeast Zone Samples No. 5 and 6 but with modifications in test procedure from that employed in Test A-29 as follows:

(1) Carboxymethyl cellulose (CMC) was added for graphite depression
(2) Copper and zinc rougher concentrates were not reground prior to cleaning
(3) First copper cleaner tailing was not diverted to zinc flotation

The best combination of copper and zinc results using this method was achieved in Test B-5 on No. 5 Sample and Test C-2 on No. 6 Sample. The primary grind employed in these tests was 80% minus 36 µm. Results are shown in Tables 18 and 19 while flowsheet, details of test procedure and comprehensive metallurgical balances are given in the Appendix. also included in the Appendix are:

(1) Table A-3, Summary of test procedure and copper flotation results for Southeast Zone samples (12 tests)
(2) Table A-4, Summary of test procedure and zinc flotation results for Southeast Zone Samples (12 tests)
(3) Table A-5, Summary of test procedure and copper cleaner flotation results for Southeast Zone No. 5 Sample (8 tests)

The best grade of copper concentrate that could be produced from the Southeast Zone No. 5 Sample after 3 stages of cleaning contained only 16.24% copper. Analysis of a similar grade of concentrate produced in Test B-4 indicated that the major contaminant was pyrite (see footnote to Table A-3). Even this modest grade was achieved at the expense of a high loss of copper to the cleaner tailings. Zinc results however were much better than those obtained on the North Zone sample. The 59.9% zinc concentrate grade was achieved after only 2 stages of cleaning and without prior regrinding of the rougher concentrate.

Table 18. Best flotation results achieved for the Southeast Zone, No. 5 Sample using SO_2 + aeration at a primary grind of 80% -36 µm (Test B-5)

Product	Wt %	Analysis %				Distribution %				Sepn eff., %
		Cu %	Zn %	Pb %	Ag ppm	Cu	Zn	Pb	Ag	Cu/Zn
Copper conc	4.84	16.24	6.52	1.98	58.5	52.9	3.9	7.2	4.7	49.1
Copper cl tail-comb	22.72	2.08	4.02	4.01	122.5	31.8	11.2	68.4	46.2	
Zinc conc	10.16	0.29	59.86	0.36	46.5	2.0	74.6	2.8	7.9	
Zinc cl tails-comb	4.04	1.13	10.09	1.22	125.8	3.1	5.0	3.7	8.4	
Final tails	58.24	0.26	0.74	0.41	33.9	10.2	5.3	17.9	32.8	
Feed (calcd)	100.00	1.48	8.15	1.33	60.2	100.0	100.0	100.0	100.0	
Copper ro conc	27.56	4.56	4.46	3.66	111.2	84.7	15.1	75.6	50.9	69.6
Zinc ro conc	14.20	0.53	45.70	0.60	69.1	5.1	79.6	6.5	16.3	

Table 19. Best flotation results achieved for the Southeast Zone, No. 6 Sample, using SO_2+ aeration at a primary grind of 80% -36 µm (Test C-2)

Product	Wt %	Analysis %				Distribution %				Sepn eff., %
		Cu %	Zn %	Pb %	Ag ppm	Cu	Zn	Pb	Ag	Cu/Zn
Copper conc	8.97	21.30	1.42	0.49	103.1	74.4	3.8	7.5	19.9	70.6
Copper cl tail-comb	23.09	2.17	3.15	1.89	109.5	19.6	21.5	74.3	54.4	
Zinc conc	4.62	0.39	49.60	0.28	35.7	0.7	68.0	2.2	3.5	
Zinc cl tails-comb	2.72	0.58	2.72	0.33	36.7	0.6	2.2	1.5	2.2	
Final tails	60.60	0.20	0.25	0.14	15.4	4.7	4.5	14.5	20.0	
Feed (calcd)	100.00	2.57	3.37	0.59	46.5	100.0	100.0	100.0	100.0	
Copper ro conc	32.06	7.53	2.66	1.50	107.7	94.0	25.3	81.8	74.3	68.7
Zinc ro conc	7.34	0.46	32.23	0.30	36.1	1.3	70.2	3.7	5.7	

On the Southeast Zone No. 6 Sample similar flotation techniques produced an improved grade of copper concentrate containing 21.3% copper with 74.4% recovery but this still fell short of the 26.0% copper concentrate grade and 90.0% copper recovery achieved on the North Zone Sample. On the other hand the 49.6% zinc concentrate grade produced from the No. 6 Sample after 2 stages of cleaning was substantially lower than that produced from the No. 5 Sample.

The substantial difference in zinc content of the copper concentrate produced from the two Southeast Zone Samples (6.52% versus 1.42%) can be attributed to differences in Zn:Cu ratios of the two ore samples - 5.5 for No. 5 Sample versus only 1.3 for the No. 6 Sample. Note the very high rejection of silver and lead to the copper cleaner tailings in the tests on both samples. This appears to be related to the addition of lime (pH 11^+) and CMC to the first copper cleaner. In tests on the North Zone sample lime addition to the copper cleaners did not result in rejection of silver to the cleaner tailings.

Mineralogical studies indicated that the sulphides in the Southeast Zone had the simplest textures and coarsest grain series. In view of the fine primary grind employed for the two Southeast Zone samples it was assumed that practically all the sulphides would have been liberated and therefore it was deemed unnecessary to regrind either the copper or zinc rougher concentrate prior to cleaning.

Graphite Depression

The various grades of CMC tried as graphite depressants were supplied by Hollimex Products Ltd., Edmonton, Alberta under the trade name "Depramin". As an alternative, the flotation of a graphite concentrate with frother prior to copper flotation was tried in Test B-2. Also in one test on the No. 6 Sample (C-4) the possible employment of humic acid as a graphite depressant was investigated.

Although the addition of CMC was effective in preventing the flotation of the naturally hydrophobic graphite, this did not result in any appreciable improvement in copper rougher concentrate grade which ranged from only 4.05 to 5.80% copper for the 8 tests on No. 5 Sample (B series). Although the differences in copper rougher concentrate grade may be

mathematically significant they are inconsequential from the selective flotation point of view. As is often the case for complex sulphide ores the unsatisfactorily low copper rougher concentrate grade was the result of poor selectivity between chalcopyrite and pyrite.

When the copper rougher concentrate were cleaned there was a wide divergence of results between some of the tests as illustrated by Fig. 1 in which concentrate grade-recovery curves are drawn using points from all 8 "B" series tests. (For Test data refer to Tables A-3 and A-5). The best copper cleaning results were obtained in Test B-8 in which the SO_2+ aeration method was employed for selective copper flotation in conjunction with Depramin XP-5. This was followed by Test B-5 using the same method but with the substitution of Depramin 75 as the graphite depressant. Note that in both tests high lime alkalinity was employed in cleaning to ensure optimum pyrite depression.

In the test in which humic acid was tried as a graphite depressant (C-4) results were similar to those obtained for the standard test (C-1). Flotation of a graphite concentrate prior to copper flotation (B-3) did not appear to be beneficial.

Lead Flotation

Because of the higher lead content in the Southeast Zone No. 5 Sample an attempt was made in Test B-2 to produce a separate lead concentrate by sequential copper-lead-zinc flotation. Sulphur dioxide was employed during the initial copper flotation step followed in succession by the addition of soda ash and cyanide to activate the galena and copper sulphate to activate the sphalerite. Results are given in Table 20.

In addition to the poor chalcopyrite-pyrite selectivity obtained during the copper flotation step most of the galena was unaffected by sulphur dioxide and floated with the chalcopyrite. Therefore, there was very little floatable galena remaining to be floated in the lead rougher flotation step. Note the very high zinc content in the so-called lead rougher concentrate. This is an indication of the presence of soluble copper minerals which were dissolved by cyanide to form copper ions in the solution which activated some of the sphalerite.

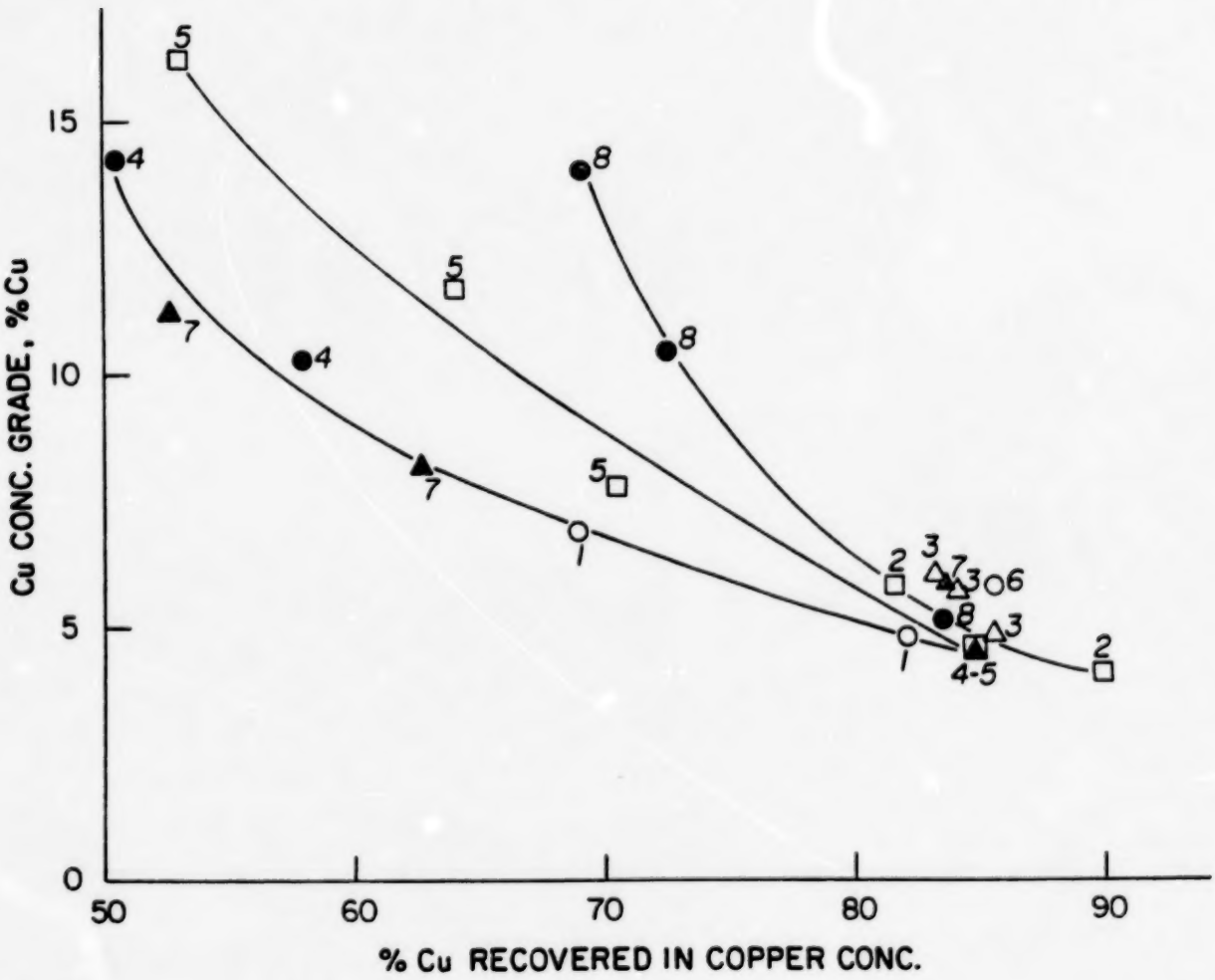

Fig. 1. Grade-recovery curves for "B" series Tests 1-8

Table 20. Results of copper-lead-zinc sequential selective flotation on Southeast Zone No. 5 Sample (Test B-2)

Product	Wt %	Analysis %			Distribution %		
		Cu	Zn	Pb	Cu	Zn	Pb
Copper ro conc	34.66	4.05	4.93	3.12	90.0	21.2	82.7
Lead ro conc	12.73	0.34	25.11	0.50	2.8	39.7	4.9
Zinc ro conc	8.04	0.45	38.05	0.58	2.3	38.0	3.5
Final tail	44.57	0.17	0.20	0.26	4.9	1.1	8.9
Feed (calcd)	100.00	1.56	8.05	1.31	100.0	100.0	100.0

At the time the first two tests were carried out on the No. 5 Sample the graphite in the froth was mistaken for galena. Upon receipt of the analyses of the test products the presence of graphite was suspected and was subsequently confirmed by mineralogical examination.

Copper-Zinc Separation on Copper Concentrate

In Test B-1 copper-zinc separation was carried out on a sample of copper concentrate produced by employing the high lime + NaCN selective copper flotation method. The copper rougher concentrate was cleaned once at high pH and then subjected to copper-zinc separation using the SO_2 method at a pulp temperature of 90°C. Results are shown in Table 21 while flowsheet and test product terminology employed are given in Fig. 2.

As was found for the North Zone ore sample the high lime + NaCN copper selective flotation method employed in Test B-1 was not as effective as the SO_2 method in depressing zinc during copper flotation. Also when the copper rougher concentrate was cleaned zinc tended to be concentrated along with the copper. However, the SO_2 + hot pulp copper-zinc separation method was effective in reducing the zinc content of the primary copper concentrate to a satisfactory level. Since the pyrite was not depressed by SO_2 it was concentrated in the separation froth product along with the chalcopyrite. The increase in copper concentrate grade from 6.8% Cu in the separation feed to 10.96% Cu in the cleaned separation froth product (secondary copper concentrate) can therefore be attributed almost entirely to the reduction in zinc content. Further upgrading of the secondary copper concentrate would require additional cleaning with lime added for pyrite depression.

Table 21. Results of copper-zinc separation on copper concentrate from Test B-1

Product	Wt %	Analysis %			Distribution %			Sep eff., % Cu/Zn
		Cu	Zn	Pb	Cu	Zn	Pb	
Overall								
1. Sec copper conc	7.60	10.96	2.56	1.52	58.3	2.5	9.2	55.8
2. Sec Cu cl tail	2.17	2.92	6.56	1.53	4.4	1.8	2.6	
3. Sepn tail	4.16	1.96	32.80	1.72	6.3	19.2	6.3	
4. Prim Cu cl tail	10.17	1.85	6.48	1.66	13.2	8.4	13.4	
5. Prim zinc conc	11.25	0.73	45.60	3.76	5.7	65.1	33.5	
6. Prim zinc cl tail	4.77	1.26	2.68	6.04	4.2	1.6	22.8	
7. Final Tail	59.43	0.19	0.20	0.26	7.9	1.5	12.2	
Feed (calcd)	100.00	1.43	7.88	1.26	100.0	100.0	100.0	
Prim Cu ro conc (1 to 4)	24.55	4.79	10.22	1.62	82.2	31.8	31.5	50.4
Comb Zn ro conc (3+5+6)	20.63	1.13	32.82	3.83	16.2	85.9	62.6	
Copper-Zinc Separation Rougher								
Sec copper ro conc	67.95	9.17	3.45	1.52	90.8	18.2	65.2	72.6
Separation tail	32.05	1.96	32.80	1.72	9.2	81.8	34.8	
Feed (Prim copper conc)	100.0	6.86	12.86	1.58	100.0	100.0	100.0	
Copper-Zinc Separation Cleaner								
Sec copper conc	77.82	10.96	2.56	1.52	93.0	57.7	77.8	35.3
Sec copper cl tail	22.18	2.92	6.56	1.53	7.0	42.3	22.2	
Feed (sec Cu ro conc)	100.00	9.17	3.45	1.52	100.0	100.0	100.0	

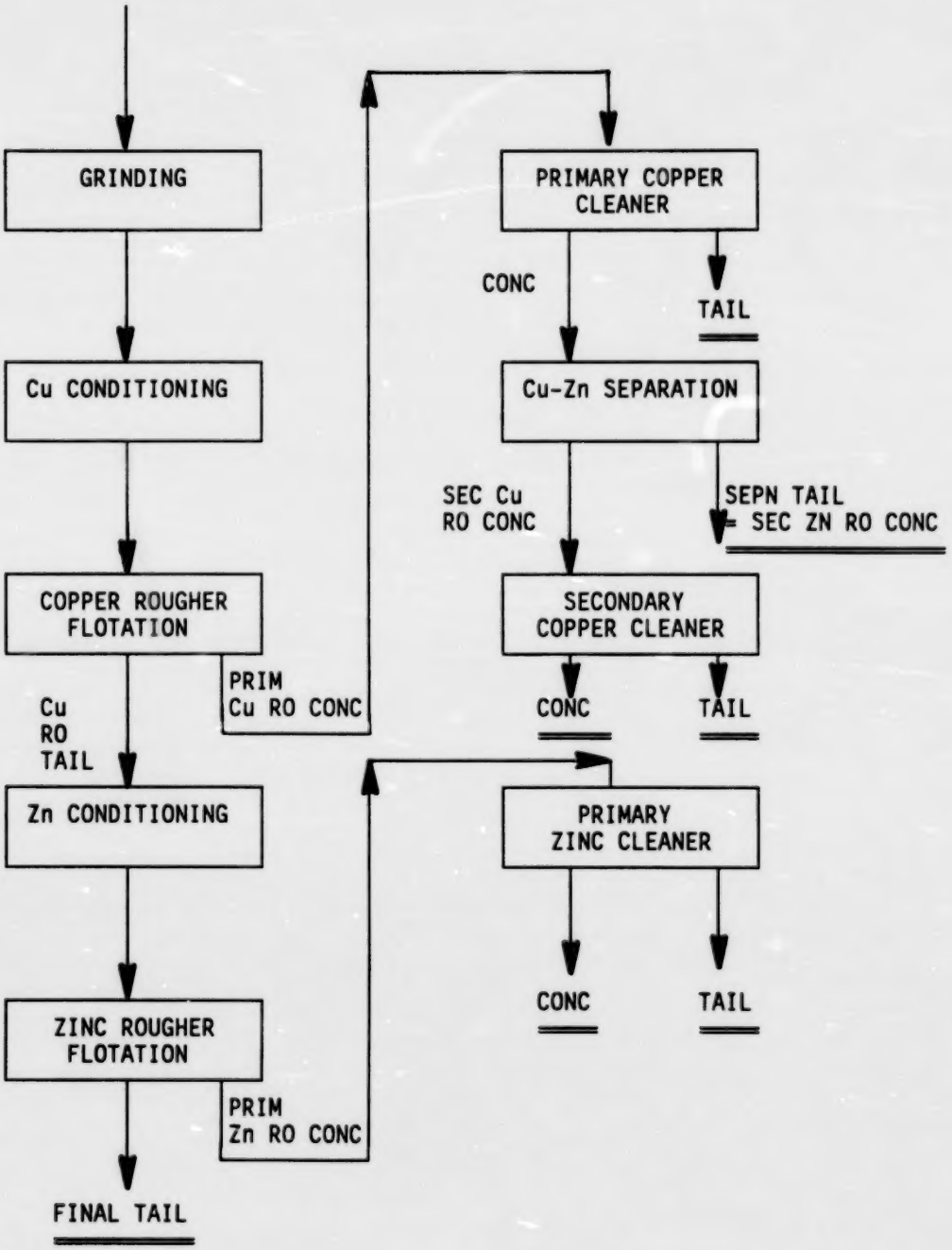

Fig. 2. Flowsheet for Test B-1 on SE Zone No. 5 Sample

TESTS ON SOUTH ZONE, NO. 8 SAMPLE

Only two tests were carried out on the South Zone No. 8 Sample employing a primary grind similar to that employed for the Southeast Zone Samples. Results are given in Tables 22 and 23. In Test D-1 the sulphur dioxide + aeration copper selective flotation method was tried while in Test D-2 a bulk copper-zinc concentrate was floated and subjected to copper-zinc separation using the sulphur dioxide + hot pulp method.

As indicated by the results, sulphur dioxide was ineffective in depressing sphalerite during copper flotation and in the copper-zinc separation step. Lack of copper/zinc selectivity is attributed to supergene alteration of sphalerite in the form of covellite-digenite rims and veinlets.

Table 22. Selective flotation results for South Zone No. 8 Sample using SO_2+ aeration method (Tests D-1)

Product	Wt %	Analysis %			Distribution %			Sep eff., % Cu/Zn
		Cu	Zn	Pb	Cu	Zn	Pb	
Copper cl conc - 2	22.81	6.69	17.38	2.10	49.1	73.6	38.0	-24.5
Copper cl conc - 1	32.77	5.64	12.97	1.91	59.4	78.9	49.5	-19.5
Copper ro conc	57.80	4.18	8.49	1.99	77.8	91.1	74.7	-13.3
Zinc ro conc	4.79	6.27	6.53	1.68	9.7	5.8	6.4	
Final tail	37.41	1.04	0.45	0.64	12.5	3.1	18.9	
Feed (calcd)	100.00	3.11	5.39	1.26	100.0	100.0	100.0	

Table 23. Results for copper-zinc separation of bulk concentrate produced from South Zone No. 8 Sample (Test D-2)

Product	Wt %	Analysis %			Distribution %			Sep eff., % Cu/Zn
		Cu	Zn	Pb	Cu	Zn	Pb	
Bulk flotation								
Bulk cleaner conc	17.22	9.66	24.56	2.43	55.0	89.9	51.0	
Bulk rougher conc	21.16	8.98	22.74	2.36	61.8	91.9	42.7	
Bulk rougher tail	78.84	1.49	0.54	0.85	38.2	8.1	57.3	
Feed (calcd)	100.00	3.08	5.24	1.17	100.0	100.0	100.0	
Copper-Zinc Separation								
Copper ro conc - 1	13.94	7.60	8.67	1.91	11.0	4.9	11.0	6.1
Copper ro conc - 2	64.63	8.80	28.69	2.17	58.9	75.5	57.8	
Sepn tail (Zn conc)	21.43	13.59	22.46	3.53	30.1	19.6	31.2	
Fees (Bulk cl conc)	100.00	9.66	24.56	2.43	100.0	100.0	100.0	

CONCLUSIONS

The use of sulphur dioxide in the pH range 4.5-5 as a sphalerite depressant in conjunction with aerative conditioning and the employment of the selective copper collector Aerofloat 238 was found to be the most effective copper selective flotation method for the North Zone ore sample. The 26% copper concentrate grade produced using this method along with a zinc content of only 1.1% and a copper recovery in the concentrate of 90% is judged to be close to the optimum that can be achieved for this ore. To obtain these results required a fine primary grind of 80% minus 33 µm, regrinding of the copper rougher concentrate prior to cleaning and three stages of cleaning with sulphur dioxide added to the first and second cleaning stages to depress sphalerite (pH 4.5) and lime added to the third cleaning stage to depress pyrite (pH 11.8).

Despite the low iron content of the sphalerite in the North Zone ore (2.4%) it was not possible to produce a high-grade zinc concentrate. The highest grade produced assayed 50.9% zinc which is equivalent to only a 79% zinc sulphide grade with the balance consisting of chalcopyrite and pyrite probably in the form of various types of middling particles with sphalerite. Whether or not it would be possible to liberate the minerals form the middling particles by further regrinding of an already very fine product and then subject the reground zinc concentrate to reverse flotation to remove liberated chalcopyrite and pyrite would require an image analysis study.

On the Southeast and South Zone ore samples not enough testing was carried out to establish the optimum primary grind or the most effective copper selective flotation method. Copper concentrate grades and copper and silver recoveries obtained for the Southeast Zone ore samples using the sulphur dioxide + aeration method were appreciably below the levels achieved for the North Zone ore sample. Therefore there is much scope for improving copper results by further testing. On the other hand zinc results obtained for the Southeast Zone Samples were better especially for the No. 5 Sample from which a high-grade zinc concentrate assaying 59.9% zinc was produced after only two stages of cleaning.

Because of supergene alteration of the sphalerite in the South Zone ore it was not possible to separate chalcopyrite from sphalerite by flotation. The application of the sulphur dioxide + aeration method resulted in the flotation of both chalcopyrite and sphalerite into what was in effect a bulk concentrate.

Except for a test on high-zinc copper concentrate produced from the Southeast Zone No. 5 Sample (Test B-1), copper-zinc separation of various products using the sulphur dioxide-hot-pulp method to depress sphalerite was ineffective. Whether or not the low Cu/Zn separation efficiency was related to the presence of high amounts of chalcopyrite-sphalerite middling particles in the feed was not determined.

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3. Schultz, N.F. "Separation efficiency, SME Trans"; Vol. 274; March 1970.

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APPENDIX

List of Abbreviations

BM	ball mill
calcd	calculated
cl	cleaner
comb	combined
flotn	flotation
prim	primary
RM	rod mill
ro	rougher
sec	secondary
sepn	separation
sep eff	separation efficiency
tail	tailing

Reagents:

Cyanamid of Canada

R350	potassium amyl xanthate
AF238	Aerofloat 238 - di-secondary butyl dixiophosphate
NaAF	Soduim aerofloat - sodium diethyl dithiophosphate
AP	Aerophine 3418A

DF250 water soluble frother - Dow Chemical Co.

Dep 40,75, C and XP-5 - various grades of sodium carboxymethylcellulose-Hollimex Products Ltd.

FLOTATION TEST REPORT

Test No: A-29 **Sample:** Tally Pond North Zone #2 Sample

Object of test: Copper-zinc selective flotation using the SO_2 method

Date: Dec. 4/85

Charge: 2000g

Test by: G.W.L.

OPERATION	Time min	% S	pH	Unit used	REAGENTS ADDED, grams									
					SO_2	R 350	AF 238	DF 250	CaO					
Grinding	75	65		7 X 14 RM										
Aeration	30		6.0	Aerator										
Copper condit - 1	10		3.8-5.3	1000-g cell	1.4									
Copper condit - 2	5		5.3	1000-g cell		0.05	0.09	0.04						
Copper roughers		35		1000-g cell										
Stage 1	1		4.9											
Stage 2	2						0.054	0.02						
Stage 3	3		4.5					0.02						
Copper ro conc regrind	45			8-in BM*										
Copper cleaner - 1				1000-g cell										
Stage 1	1		4.6		0.1									
Stage 2	1							0.02						
Stage 3	4							0.02						
Copper cleaner - 2														
Stage 1	2		4.5	500-g cell	0.175									
Stage 2	2													
Copper cleaner - 3	4		11.8	500-g cell					0.60					

REMARKS: * with ceramic ball charge
Primary grind, 80% minus 33um

FLOTATION TEST REPORT

Test No: A-29	Sample: Tally Pond North Zonc #2 Sample	Date:
Object of test:		Charge:
		Test by:

OPERATION	Time min	% S	pH	Unit used	REAGENTS ADDED, grams									
					$CuSO_4$	CaO	NaAF	DF 250						
Aeration of Cu ro	30		11.9	Aerator	2.0	6.0								
tail + Cu cl tails 1+2														
Zinc conditioning*	10		ca 11.0	1000-g cell	2.0									
Zinc roughers														
Stage 1	1						0.10	0.04						
Stage 2	1						0.05							
Stage 3	1							0.02						
Zinc ro conc regrind	45			8-in BM**										
Zinc cleaner - 1				500-g cell										
Stage 1	1													
Stage 2	2							0.04						
Zinc cleaner - 2	3			250-g cell										
Zinc cleaner - 3	1½			250-g cell										

REMARKS: * required additional $CuSO_4$ and conditioning to activate sphalerite
** with ceramic ball charge

METALLURGICAL BALANCE

Test No: A-29 | **Sample:** Tally Pond North Zone #2 Sple | **Date:** Dec. 4/85

PRODUCT	WT %	ANALYSIS				DISTRIBUTION %			
		Cu %	Zn %	Pb %	Ag g/t	Cu	Zn	Pb	Ag
Copper conc	19.00	26.00	1.10	0.50	77.48	90.01	6.53	37.20	41.10
Copper cl tail - 3	2.69	4.00	2.49	0.91	79.38	1.96	2.09	9.59	5.96
Zinc conc	4.35	2.38	50.89	0.40	66.93	1.89	69.20	6.81	8.13
Zinc cl tail - 3	0.91	2.13	27.80	0.37	89.75	0.35	7.91	1.33	4.18
Zinc cl tail - 2	0.76	1.38	11.30	0.32		0.19	2.69	0.94	
Zinc cl tail - 1	5.24	0.74	3.10	0.23	39.35	0.71	5.08	4.74	5.76
Final tail	67.05	0.40	0.31	0.15	18.63	4.89	6.50	39.39	34.87
Feed (calcd)	100.00	5.49	3.20	0.26	35.82	100.00	100.00	100.00	100.00
Feed (assay)		5.20	3.20	0.28	34.9				
Calcd Analyses									
Copper cleaner conc 2	21.69	23.27	1.27	0.55	77.74	91.97	8.62	46.79	47.06
Zinc cleaner conc-2	5.26	2.34	46.90	0.40	–	2.24	77.11	8.14	–
Zinc cleaner conc-1	6.02	2.22	42.40	0.39	73.26	2.43	79.80	9.08	12.31
Zinc rougher conc	11.26	1.53	24.11	0.31	57.48	3.14	84.88	13.82	18.07

REMARKS: Copper cleaner tails 1 and 2 mixed with copper rougher tailing prior to zinc flotation

FLOTATION TEST REPORT

Test No: B-5 **Sample:** Tally Pond Southeast Zone - #5 Sample **Date:** January 14/86

Object of test: Copper-zinc selective flotation using the SO_2 method with Depramin "75" added for graphite depression **Charge:** 2000g **Test by:** G.W.L.

OPERATION	Time min	% S	pH	Unit used	REAGENTS ADDED, grams									
					SO_2	Dep 75	R 350	AF 238	DF 250	CaO				
Grinding	60	65		7 X 14 RM										
Aeration	30			Aerator										
Copper condit - 1	10		4.8-5.1	1000-g cell	2.0									
Copper condit - 2	2					0.5								
Copper condit - 3	2						0.02							
Copper roughers		35		1000-g cell										
Stage 1	½							0.054	0.02					
Stage 2	1							0.036						
Condit - 1	1					0.25								
Condit - 2	1							0.036	0.02					
Stage 3	1													
Copper cleaner - 1				500-g cell										
Condit	1		11.7			0.2				2.0				
Stage 1	1						0.01							
Stage 2	2						0.01		0.02					
Copper cleaner - 2	2			500-g cell										
Copper cleaner - 3	1½			250-g cell										

REMARKS: Primary grind, 80% minus 36um

FLOTATION TEST REPORT

Test No: B-5	Sample: Tally Pond Southeast Zone - #5 Sample	Date:
Object of test:		Charge:
		Test by:

OPERATION	Time min	% S	pH	Unit used	REAGENTS ADDED, grams									
					$CuSO_4$	CaO	R 350	NaAF						
Zinc conditioning	10		11.4	1000-g cell	2.0	5.0								
Zinc roughers														
Stage 1	½						0.01	0.13						
Stage 2	½						0.01	0.05						
Stage 3	1						0.01	0.05						
Zinc cleaner - 1				500-g cell										
Stage 1	1							0.05						
Stage 2	1							0.025						
Zinc cleaner - 2	1½			250-g cell										

REMARKS:

METALLURGICAL BALANCE

Test No: B-5	Sample: Tally Pond Southeast Zone - #5 Sple	Date: January 14/86

PRODUCT	WT %	ANALYSIS				DISTRIBUTION %			
		Cu %	Zn %	Pb %	Ag g/t	Cu	Zn	Pb	Ag
Copper conc	4.84	16.24	6.52	1.98	58.47	52.95	3.87	7.19	4.70
Copper cl tail-3	3.30	4.96	5.68	2.40	38.66	11.03	2.30	5.94	2.12
Copper cl tail-2	5.31	1.82	4.32	4.20	139.37	6.50	2.81	16.74	12.29
Copper cl tail-1	14.11	1.50	3.52	4.32	135.73	14.26	6.09	45.76	31.79
Zinc conc	10.16	0.29	59.86	0.36	46.59	1.99	74.63	2.75	7.86
Zinc cl tail-2	0.98	1.18	16.00	1.28	125.77	0.78	1.93	0.94	8.43
Zinc cl tail-1	3.06	1.11	8.20	1.20		2.29	3.08	2.75	
Final tail	58.24	0.26	0.74	0.41	33.94	10.20	5.29	17.93	32.81
Feed (calcd)	100.00	1.48	8.15	1.33	60.24	100.00	100.00	100.00	100.00
Feed (assay)		1.52	8.55	1.25	54.90				
Calcd Analyses									
Copper cl conc-2	8.14	11.67	6.21	2.15	50.44	63.98	6.17	13.13	6.82
Copper cl conc-1	13.45	7.78	5.45	2.96	85.55	70.48	8.98	29.87	19.11
Copper ro conc	27.56	4.56	4.46	3.66	111.24	84.74	15.07	75.63	50.90
Zinc cl conc-1	11.14	0.37	56.00	0.44		2.77	76.56	3.69	
Zinc ro conc	14.20	0.53	45.70	0.60	69.12	5.06	79.64	6.44	22.73

REMARKS:

FLOTATION TEST REPORT

Test No: C-2 | **Sample:** Tally Pond Southeast Zone - #6 Sample | **Date:** January 30/86

Object of test: Copper-zinc selective flotation using the SO_2 method with Depramin "C" added for graphite depression | **Charge:** 2000g | **Test by:** G.W.L.

OPERATION	Time min	% S	pH	Unit used	REAGENTS ADDED, grams									
					SO_2	Dep C	R 350	AF 238	DF 250	$CuSO_4$	CaO	NaAF		
Grinding	75	50		7 X 14 RM										
Aeration	30		6.7	Aerator										
Copper condit - 1	10		4.8-5.0	1000-g cell	2.4									
Copper condit - 2	2					0.3								
Copper condit - 3	1						0.02	0.054						
Copper roughers				1000-g cell										
Stage 1	½													
Stage 2	½								0.02					
Condit - 1	1					0.1								
Condit - 2	1							0.036	0.02					
Stage 3	1													
Copper cleaners														
No. 1	1½		11.5	500-g cell							2.0			
No. 2	1½		11.2	500-g cell										
Zinc conditioning	10		11.6							2.0	5.2			
Zinc rougher -Stage1	½						0.01					0.13		
Zinc rougher-Stage 2	1						0.01					0.05		
Zinc cleaner - 1	1½		11.2	250-g cell										
Zinc cleaner - 2	1		11.0	250-g cell										

REMARKS: Primary grind, 80% minus 36um

METALLURGICAL BALANCE

Test No: C-2 | **Sample:** Tally Pond Southeast Zone - #6 Sple | **Date:** January 30/86

PRODUCT	WT %	ANALYSIS				DISTRIBUTION %			
		Cu %	Zn %	Pb %	Ag g/t	Cu	Zn	Pb	Ag
Copper conc	8.97	21.30	1.42	0.49	103.08	74.41	3.78	7.51	19.88
Copper cl tail-2	8.93	2.80	1.86	1.20	93.05	9.74	4.93	18.26	17.87
Copper cl tail-1	14.16	1.78	3.96	2.32	119.86	9.82	16.63	56.03	36.49
Zinc conc	4.62	0.39	49.60	0.28	35.68	0.70	67.97	2.20	3.54
Zinc cl tail-2	0.82	0.63	3.84	0.34	36.70	0.20	0.94	0.48	2.15
Zinc cl tail-1	1.90	0.56	2.24	0.32		0.41	1.26	1.04	
Final tail	60.60	0.20	0.25	0.14	15.40	4.72	4.49	14.46	20.07
Feed (calcd)	100.00	2.57	3.37	0.59	46.51	100.00	100.00	100.00	100.00
Feed (assay)		2.69	3.83	0.64	45.14				
Calcd Analyses									
Copper cl conc-1	17.90	12.07	1.64	0.84	54.54	84.15	8.71	25.79	30.58
Copper ro conc	32.06	7.53	2.66	1.50	62.19	93.97	25.34	81.82	62.46
Zinc cl conc-1	5.44	0.43	48.10	0.29		0.90	68.91	2.68	
Zinc ro conc	7.34	0.46	32.23	0.30	36.06	1.31	70.17	3.72	8.30

REMARKS:

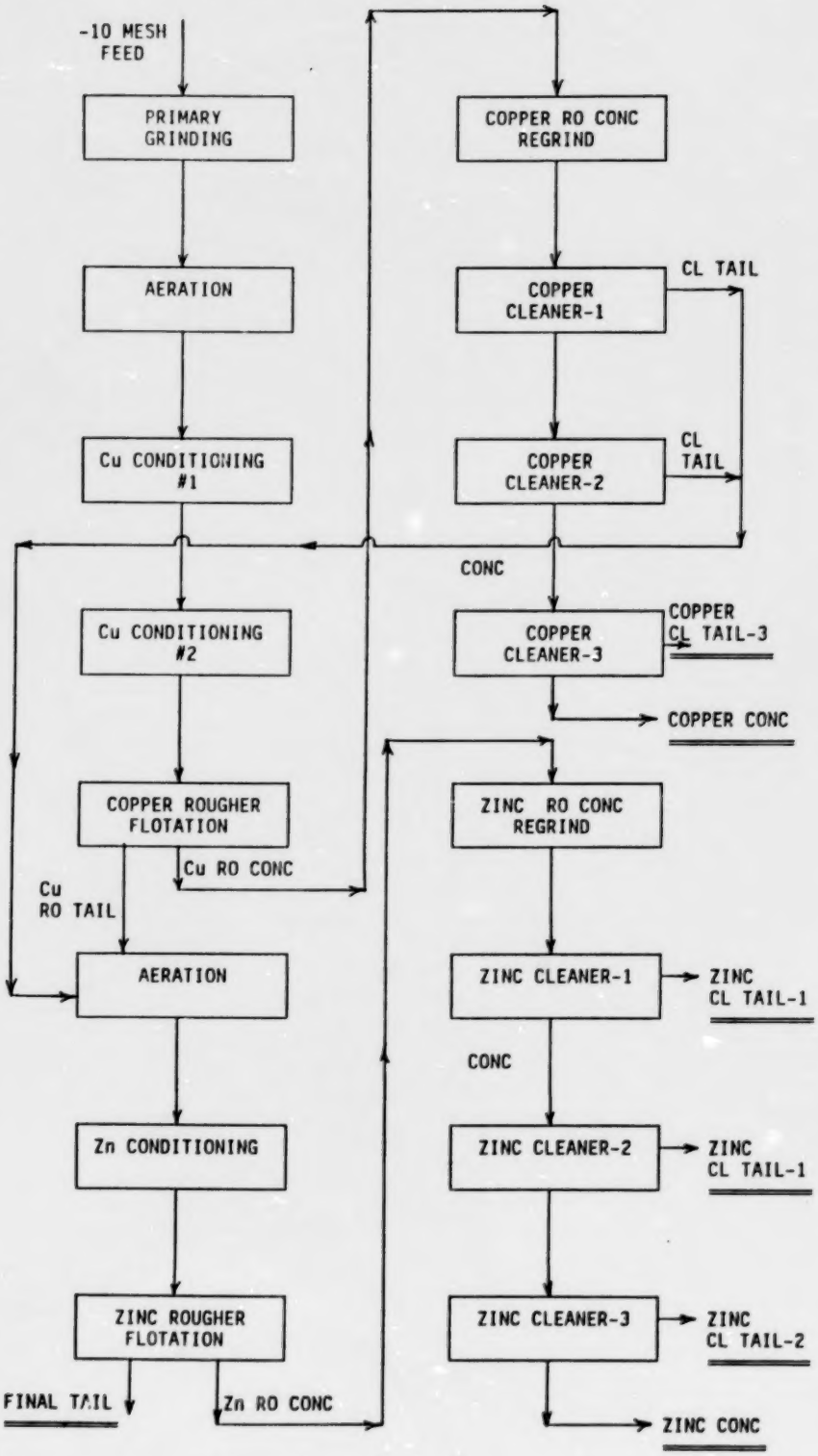

Fig. A-1 Flowsheet for best results achieved for North Zone No. 2 Sample (Test A-29)

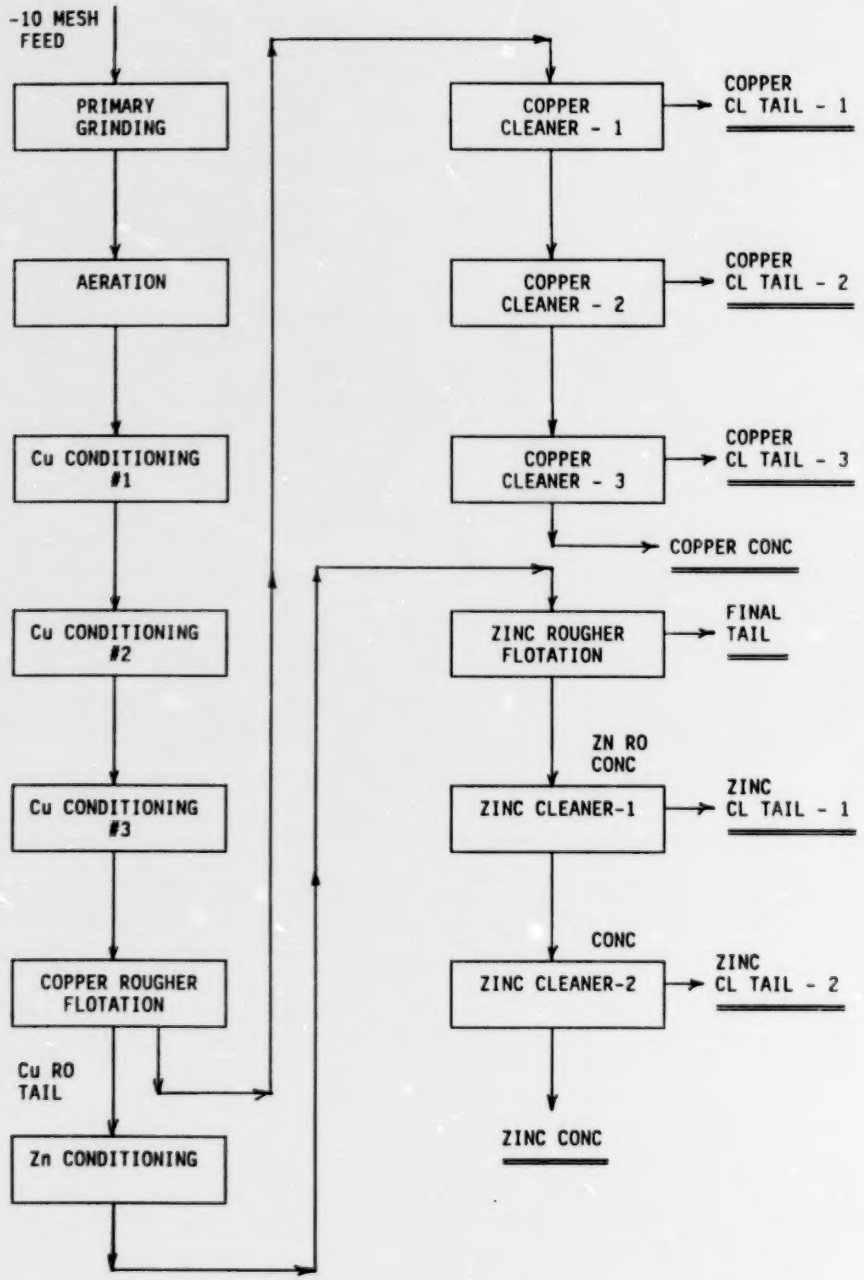

Fig. A-2 Flowsheet for Tests B-5 and C-2* on Southeast Zone Samples

* In this test only two stages of copper cleaning were employed.

Table A-1 Summary of test procedure and copper flotation results for North Zone No. 2 Sample

Test No. Date	Selective flotn method and grind K_{80} -µm	Collector added g/t	Rougher Skim time - min	Copper rougher pH	Product	Copper flotation results						Remarks
						Wt %	Analysis % Cu	Analysis % Zn	Distribution % Cu	Distribution % Zn	Sep eff., %	
A-1 Feb 27	SO_2 - conditioned in cell 45	63 - AF238 80 - R350 143	4	5.5 -4.5	Cl conc 2 Cl conc 1 Ro conc Ro tail	7.16 8.99 16.09 83.91	27.22 23.92 17.82 2.72	0.56 0.78 1.10 3.57	37.9 41.8 55.7 44.3	1.3 2.2 5.6 94.4	36.3 39.6 50.1	Added 18 g/t AF238 to copper cleaner 2
A-2 Feb 27	High lime - conditioned in cell 45	81 - AF238 50 - R350 131	4½	12.1 -11.5	Cl conc 2 Cl conc 1 Ro conc Ro tail	12.69 16.22 21.59 78.41	27.33 23.24 18.78 1.60	1.92 2.50 2.79 3.21	65.3 71.0 76.3 23.7	7.8 13.0 19.3 80.7	57.5 58.0 57.0	
A-3 Feb 28	High lime + aeration 45	81 - AF238 50 - R350 131	4	11.7 -11.5	Cl conc 3 Cl conc 2 Cl conc 1 Ro conc Ro tail	15.07 16.42 17.80 21.14 78.86	25.97 24.54 23.13 20.05 1.30	5.25 5.79 6.05 5.74 2.67	74.4 76.6 78.3 80.6 19.4	23.9 28.7 32.5 36.6 63.4	50.5 47.9 45.8 44.0	
A-4 Mar 13	Soda ash + NacN + aeration 45	63 - AF238 25 - R350 88	4	9.4 -8.8	Cl conc 2 Ro tail	19.65 80.35	22.53 1.31	2.13 3.19	80.8 19.2	14.0 86.0	66.8	Copper cleaner tails to zinc flotation
A-5 Mar 14	as above 45	81 - AF238	4	8.9 -8.8	Cl conc 2 Ro tail	21.12 78.88	20.30 1.27	1.86 3.31	81.0 19.2	13.1 86.9	67.9	Copper cleaner tails to zinc flotation
A-6 Apr 2	High lime + aeration 39	81 - AF238 50 - R350 131	4	11.9 -11.6	Ro conc Ro tail	26.19 73.81	18.61 0.88	5.43 2.83	88.2 11.8	40.5 59.5	47.7	Repeat of A-3 at finer grind - ro conc not cleaned

Table A-1 Summary of copper flotation results on North Zone No. 2 Sample

Test No. Date	Selective flotn method and grind K_{80} -µm	Collector added g/t	Rougher Skim time - min	Copper rougher pH	Product	Copper flotation results						Remarks
						Wt %	Analysis % Cu	Analysis % Zn	Distribution % Cu	Distribution % Zn	Sep eff., %	
A-7 Apr 3	High lime + aeration 33	99 - AF238 50 - R350 149	6	11.9	Cl conc 1 Ro conc Ro tail	11.34 25.88 74.12	17.97 19.09 0.66	1.44 3.37 3.50	37.5 91.0 9.0	4.7 25.1 74.9	32.8 65.9	Repeat of A-6 but (1) finer primary grind (2) clean ro conc with SO_2 in hot pulp
A-8 Apr 12	High lime + NacN + aeration 24	144 - AF238 50 - R350 194	7	11.0	Cl conc 2 Cl conc 1 Ro conc Ro tail	25.82 35.41 39.26 60.74	18.56 14.26 13.11 0.37	2.71 3.73 4.11 2.71	89.0 94.0 95.9 4.1	21.5 40.5 49.4 50.6	67.5 53.5 46.5	To try: (1) very fine grind (2) NacN along with high lime
A-9 Apr 27	High lime + aeration 33	144 - AF238 50 - R350 194	7	11.5	Ro conc Ro tail	40.82 59.18	12.85 0.29	6.01 1.32	96.8 3.2	75.9 24.1	20.9	Repeat of A-7 but with increases in collector and skimming time
A-10 May 1	High lime + aeration 33	99 - AF238 50 - R350 149	6	11.7	Cl conc 2 Cl conc 1 Ro conc Ro tail	22.93 24.06 28.90 71.10	20.58 19.78 16.80 0.50	5.11 5.07 4.58 2.61	90.5 91.3 93.1 6.9	36.9 38.4 41.6 58.4	53.6 52.9 51.5	Repeat of A-7 but ro conc cleaned without reagents
A-11 May 1	High lime + aeration 33	99 - AF238 50 - R350 149	6	11.7	Ro conc Ro tail	25.85 74.15	18.63 0.74	3.26 3.12	89.8 10.2	26.7 73.3	63.1	Repeat of A-10 -ro conc not cleaned

Table A-1 Summary of copper flotation results on North Zone No. 2 Sample

Test No. Date	Selective flotn method and grind K_{80} -µm	Collector added g/t	Rougher Skim time - min	Copper rougher pH	Product	Copper flotation results						Remarks
						Wt %	Analysis % Cu	Analysis % Zn	Distribution % Cu	Distribution % Zn	Sep eff., %	
A-12 Aug 19	Soda ash + NaCN + aeration 33	99 - AF238 25 - R350 124	5	8.8-8.45	Cl conc 3 Cl conc 2 Cl conc 1 Ro conc Ro tail	20.49 22.44 26.52 41.82 58.18	21.06 19.59 17.01 11.24 0.78	1.71 1.85 2.14 1.93 3.73	83.7 85.3 87.5 91.2 8.8	11.8 13.9 19.1 27.2 72.8	71.9 71.4 68.4 64.0	Repeat to Test A-4 but a finer grind and reground ro conc 50 min with 250 g/t soda ash 50 g/t NacN
A-14 Aug 23	High lime - conditined in cell 33	99 - AF238 50 - R350 149	6	11.6-10.95	Cl conc 2 Cl conc 1 Ro conc Ro tail	22.70 24.80 36.24 63.76	19.46 18.19 13.12 0.43	10.70 9.98 7.49 0.52	87.3 89.2 94.6 5.4	79.7 81.3 89.1 10.9	7.6 7.9 5.5	Ro conc reground 45 min with 500 g/t lime
A-15 Apr 23	High lime + aeration 33	99 - AF238 50 - R350 149	6	11.45	Cl conc 2 Cl conc 1 Ro conc Ro tail	21.32 23.69 35.37 64.63	21.55 19.97 14.22 0.54	6.18 5.89 4.36 2.58	85.4 87.9 93.5 6.5	41.0 43.4 48.1 51.9	44.4 44.5 45.4	Repeat of Test A-10 (no regrind)
A-16 Sept 23	High lime + NaCN conditioned in cell 33	99 - AF238 65 - R350 164	6	11.45	Cl conc 2 Cl conc 1 Ro conc Ro tail	18.69 20.85 39.47 60.53	24.30 22.13 12.99 0.27	2.70 2.68 2.92 3.34	85.8 87.2 96.9 3.1	15.9 17.6 36.3 63.7	69.9 69.6 60.6	Repeat of Test A-14 but with 125 g/t NacN added to grind
A-17 Sept 24	Soda ash + NaCN + aeration 33	99 - AF238 25 - R350 124	6	8.8	Cl conc 3 Cl conc 2 Cl conc 1 Ro conc Ro tail	32.57 34.00 42.73 64.52 35.48	14.37 13.86 11.47 7.83 0.85	6.57 6.35 5.42 3.75 2.09	87.4 88.0 91.6 94.4 5.6	67.7 68.4 73.4 76.5 23.5	19.7 19.6 18.2 17.9	Repeat of Test A-12 with different operator

Table A-1 Summary of copper flotation results on North Zone No. 2 Sample

Test No. Date	Selective flotn method and grind K_{80} -μm	Collector added g/t	Rougher Skim time - min	Copper rougher pH	Product	Copper flotation results						Remarks
						Wt %	Analysis % Cu	Analysis % Zn	Distribution % Cu	Distribution % Zn	Sep eff., %	
A-18 Sept 25	Soda ash + NaCN + aeration 33	99 - AF238 28 - AP 127	6	8.8	Cl conc 3 Cl conc 2 Cl conc 1 Ro conc Ro tail	30.69 32.35 37.13 41.72 58.28	15.60 14.87 13.09 11.83 0.83	2.37 2.38 2.50 2.59 3.58	88.4 88.8 89.7 91.1 8.9	23.0 24.3 29.4 34.1 65.9	65.4 64.5 60.3 57.0	Repeat to Test A-17 but with Aerophine 3418A in place of R350
A-19 Sept 26	Soda ash + NaCN + aeration 33	100 - AF249	6	8.8	Cl conc 3 Cl conc 2 Cl conc 1 Ro conc Ro tail	36.14 41.85 55.03 68.08 31.92	13.90 12.19 9.45 7.79 0.75	2.04 2.18 2.40 2.40 4.38	90.7 92.1 93.9 95.7 4.3	23.3 28.8 41.7 55.9 44.1	67.4 63.3 52.2 39.8	Repeat of Test A-17 but with Aerofloat 249 as the sole collector
A-21 Oct 10	High lime + NaCN conditioned in cell 33	99 - AF238 65 - R350 164	6	11.6	Cl conc 2 Cl conc 1 Ro conc Ro tail	33.61 35.70 45.03 54.97	15.90 15.07 12.23 0.28	9.60 9.06 7.23 0.08	94.7 95.3 97.3 2.7	97.7 97.9 98.7 1.3	-3.0 -2.6 -1.4	Repeat of Test A-16
A-22 Oct 22	High lime + aeration 33	99 - AF238 65 - R350 164	6	11.6	Cl conc 3 Cl conc 2 Cl conc 1 Ro conc Ro tail	9.76 15.53 20.70 39.63 60.37	20.72 19.77 20.03 13.04 0.25	1.14 1.30 1.82 6.34 1.04	38.0 57.7 77.9 97.2 2.8	3.5 6.4 12.0 80.0 20.0	34.5 51.3 65.9 17.2	To try SO_2 as depressant in regrind and copper cleaners
A-23 Oct 23	High lime + NaCN conditioned in cell 33	99 - AF238 25 - R350 124	6	11.6	Cl conc 2 Cl conc 1 Ro conc Ro tail	29.01 32.20 43.30 57.70	17.44 15.25 11.98 0.24	10.00 9.18 7.15 0.17	95.0 95.8 97.4	90.8 92.5 96.9	4.2 3.3 0.5	NacN to grind increased to 250 g/t

Table A-1 Summary of copper flotation results on North Zone No. 2 Sample

Test No. Date	Selective flotn method and grind K_{80} -µm	Collector added g/t	Rougher Skim time - min	Copper rougher pH	Product	Copper flotation results						Remarks
						Wt %	Analysis % Cu	Analysis % Zn	Distribution % Cu	Distribution % Zn	Sep eff., %	
A-25 Nov 15	SO_2 - conditioned in cell 33	72 - AF238 75 - R350 147	5	5.6	Cl conc Ro conc Ro tail	49.37 69.42 30.58	8.88 7.03 1.40	1.12 1.62 7.04	82.6 91.9 8.1	16.9 34.3 65.7	65.7 57.6	(1) H_2S evolved during conditioning (2) No regrind
A-26 Nov 18	High lime + NacN conditioned in cell 33	99 - AF238 65 - R350 164	6	11.8	Cl conc 2 Ro conc 1 Ro conc Ro tail	27.25 28.79 40.01 59.99	18.72 17.80 13.02 0.25	8.48 8.11 6.26 1.20	95.2 95.6 97.2 2.8	71.7 72.4 79.7 20.3	23.5 23.2 17.5	Repeat of Test A-16 on newly-crushed last quarter of North zone, Sample No. 2
A-27 Nov 19	SO_2 + aeration 33	90 - AF238 25 - R350 115	6	5.4	Cl conc 2 Cl conc 1 Ro conc Ro tail	23.00 27.91 38.73 61.27	20.42 17.29 12.84 0.38	1.77 2.25 3.37 2.56	90.3 92.8 95.6 4.4	14.2 21.8 45.4 54.6	76.1 71.0 50.2	No regrind
A-28 Nov 26	SO_2 + aeration 33	72 - AF238 25 - R350 97	6	5.6	Cl conc Ro tail	20.86 79.14	23.40 0.66	1.17 3.67	90.3 9.7	7.8 92.2	82.5	(1) Reground ro conc (2) Cleaned twice with SO_2 (3) Cl tails to zinc flotn
A-29 Dec 4	SO_2 + aeration 33	72 - AF238 25 - R350 97	6	5.3	Cl conc - 3 Cl conc - 2 Ro tail	19.00 21.69 78.31	26.00 23.27 0.56	1.10 1.27 3.73	90.0 92.0 8.0	6.5 8.6 91.4	83.5 83.4	Same as A-28 except cleaned a third time with lime, pH 11.8
A-30 Dec 12	SO_2 + aeration 33	72 - AF238 25 - R350 97	6	4.8	Cl conc Ro tail	17.91 82.09	24.95 0.75	1.10 3.71	87.8 12.2	6.6 93.4	81.2	Repeat of A-28 but cleaned twice with lime (pH 11-11.5) instead of SO_2

Note: Tests A-1 to A-15 on first half of sample
A-16 to A-23 on third quarter of sample
A-24 to A-30 on remaining quarter of sample

Table A-2 Summary of test procedure and zinc flotation results for North Zone No. 2 Sample

Test No.	Cu selective flotn method	Grind K_{80}	Reagents added, g/t			Rougher skim time min	Rougher conc regrind	Cu cl tail to zinc flotn	Product	Wt %	Analysis % Distribution %			
			$CuSO_4$	R350	NaAF						Zn	Cu	Zn	Cu
A-1	SO_2 conditioned in cell	45	1000	-	63	1	No	No	Zn ro conc	9.41	9.83	0.69	25.9	2.4
									Zn ro tail	90.59	2.92	2.93	74.1	97.6
									Feed (calcd)	100.00	3.57	2.72	100.0	100.0
A-2	High lime conditioned in cell	45	1000	-	101	1½	No	No	Zn cl conc	6.76	41.89	3.41	88.2	14.4
									Zn ro conc	9.75	30.23	3.73	91.8	22.7
									Zn ro tail	90.25	0.29	1.37	8.2	77.3
									Feed (calcd)	100.00	3.21	1.60	100.0	100.0
A-3	High lime + aeration	45	1000	10	89	2	No	No	Zn cl conc 3	5.36	41.72	3.84	83.9	15.9
									Zn cl conc 2	7.88	30.50	5.04	90.0	30.6
									Zn cl conc 1	11.46	21.84	5.27	93.8	46.6
									Zn ro conc	15.59	16.35	4.64	95.6	55.9
									Zn ro tail	84.41	0.14	0.68	4.4	44.1
									Feed (calcd)	100.00	2.67	1.30	100.0	100.0
A-4	Soda ash + NaCN + aeration	45	1000	10	89	3	No	Yes	Zn cl conc	6.79	41.31	2.75	87.8	14.2
									Zn ro conc	9.52	30.20	2.95	90.1	21.4
									Zn ro tail	90.48	0.35	1.14	9.9	78.6
									Feed (calcd)	100.00	3.19	1.31	100.0	100.0
A-5	as above	45	1000	-	51	3	No	Yes	Zn ro conc	11.25	26.05	3.81	88.5	33.7
									Zn ro tail	88.75	0.43	0.95	11.5	66.3
									Feed (calcd)	100.00	3.31	1.27	100.0	100.0

Table A-2 Summary of test procedure and zinc flotation results for North Zone No. 2 Sample

Test No.	Cu selective flotn method	Grind K_{80} µm	Reagents added, g/t			Rougher skim time min	Rougher conc regrind	Cu cl tail to zinc flotn	Product	Wt %	Analysis % Distribution %			
			$CuSO_4$	R350	NaAF						Zn	Cu	Zn	Cu
A-6	High lime + aeration	39	1000	10	89	2	No	No	Zn cl conc 2	8.48	31.04	3.98	93.0	38.4
									Zn cl conc 1	10.77	24.83	3.83	94.6	46.9
									Zn ro conc	15.28	17.73	3.31	95.8	57.6
									Zn ro tail	84.72	0.14	0.44	4.2	42.4
									Feed (calcd)	100.00	2.83	0.88	100.0	100.0
A-7	High lime + aeration	33	1000	10	114	3	No	No	Zn cl conc 2	8.65	40.05	2.46	92.2	30.0
									Zn cl conc 1	11.05	30.05	2.57	94.9	43.0
									Zn ro conc	19.51	17.41	2.19	97.0	64.7
									Zn ro tail	80.49	0.13	0.29	3.0	35.3
									Feed (calcd)	100.00	3.50	0.66	100.0	100.0
A-8	High lime + 50 g/t NaCN + aeration	24	1000	-	38	3	No	No	Zn cl conc	6.50	38.44	0.76	92.0	13.4
									Zn ro conc	10.70	23.70	0.76	93.4	22.1
									Zn ro tail	89.30	0.20	0.32	6.6	77.9
									Feed (calcd)	100.00	2.71	0.37	100.0	100.0
A-10	High lime + aeration	33	500	10	114	3	No	No	Zn cl conc	8.17	29.67	1.94	92.9	31.5
									Zn ro conc	11.82	21.01	1.87	95.3	43.9
									Zn ro tail	88.18	0.14	0.32	4.7	56.1
									Feed (calcd)	100.00	2.61	0.50	100.0	100.0

Table A-2 Summary of test procedure and zinc flotation results for North Zone No. 2 Sample

Test No.	Cu selective flotn method	Grind K_{80} µm	Reagents added, g/t			Rougher skim time min	Rougher conc regrind	Cu cl tail to zinc flotn	Product	Wt %	Analysis %		Distribution %	
			$CuSO_4$	R350	NaAF						Zn	Cu	Zn	Cu
A-11	High lime + aeration	33	250	10	114	3	No	No	Zn cl conc 3	7.81	35.64	2.97	89.1	31.5
									Zn cl conc 2	9.64	29.84	3.07	92.1	40.1
									Zn ro conc 1	11.37	25.67	3.00	93.5	46.3
									Zn ro conc	16.90	17.59	2.69	95.2	61.7
									Zn ro tail	83.10	0.18	0.34	4.8	38.3
									Feed (calcd)	100.00	3.12	0.74	100.0	100.0
A-27	SO_2 + aeration	33	1000	-	51	3	No	No	Zn cl conc 2	5.30	46.50	1.41	92.2	20.3
									Zn cl conc 1	6.86	36.80	1.37	94.4	25.5
									Zn ro conc	9.24	27.65	1.24	95.5	31.1
									Zn ro tail	90.76	0.13	0.28	4.5	68.9
									Feed (calcd)	100.00	2.67	0.37	100.0	100.0
A-28	SO_2 + aeration	33	1500	-	76	3	Yes	Yes	Zn cl conc 2	5.93	50.57	2.80	81.7	25.0
									Zn cl conc 1	6.67	46.75	2.83	85.0	28.4
									Zn ro conc	10.99	31.36	2.40	93.9	39.7
									Zn ro tail	89.01	0.25	0.45	6.1	60.3
									Feed (calcd)	100.00	3.67	0.66	100.0	100.0
A-29	SO_2 + aeration	33	2000	-	76	3	Yes	Yes	Zn cl conc 3	5.55	50.89	2.38	75.7	23.5
									Zn cl conc 2	6.71	46.90	2.34	84.3	27.9
									Zn cl conc 1	7.68	42.40	2.22	87.2	30.3
									Zn ro conc	14.37	24.11	1.53	92.8	39.1
									Zn ro tail	85.63	0.31	0.40	7.2	60.9
									Feed (calcd)	100.00	3.73	0.56	100.0	100.0

Table A-2 Summary of test procedure and zinc flotation results for North Zone No. 2 Sample

Test No.	Cu selective flotn method	Grind K_{80} µm	Reagents added, g/t			Rougher skim time min	Rougher conc regrind	Cu cl tail to zinc flotn	Product	Wt %	Analysis %		Distribution %	
			$CuSO_4$	R350	NaAF						Zn	Cu	Zn	Cu
A-30	SO_2 + aeration	33	1500	5	76	3	Yes	Yes	Zn cl conc 3	5.45	49.68	3.89	72.9	28.1
									Zn cl conc 2	6.50	46.82	3.92	81.9	33.8
									Zn ro conc 1	7.34	43.13	3.78	85.2	36.8
									Zn ro conc	12.87	27.25	2.75	94.4	46.9
									Zn ro tail	87.13	0.24	0.46	5.6	53.1
									Feed (calcd)	100.00	3.72	0.75	100.0	100.0

Table A-3 Summary of test procedure and copper flotation results for Southeast Zone No. 5 and 6 Samples

Test No. Date	Selective flotn method and grind K_{80} -µm	Collector added g/t	Depramin added g/t	Rougher Skim time - min	Copper rougher pH	Product	Copper flotation results							
								Analysis %			Distribution %			Sep eff., %
							Wt %	Cu	Zn	Pb	Cu	Zn	Pb	
B-1 Nov. 22 1985	High lime + NaCN (0.1 g/t) - conditioned in cell, 36	99 - AF238 30 - R350 129	0	11.3	11.3	Cl conc 1	14.38	6.86	12.86	1.59	69.0	23.5	18.1	45.5
						Ro conc	24.55	4.79	10.22	1.62	82.2	31.8	31.4	50.4
						Ro tail	75.45	0.34	7.13	1.15	17.8	68.2	68.6	
						Feed (calcd)	100.00	1.43	7.88	1.26	100.0	100.0	100.0	
B-2 Dec. 5 1985	SO_2 + aeration 36	45 - AF238 10 - R350 55	0	4.7	4.7	Cl conc 1	21.99	5.78	3.63	1.57	81.6	9.9	26.5	71.7
						Ro conc	34.66	4.05	4.93	3.12	90.0	21.2	82.7	68.8
						Ro tail	65.34	0.24	9.71	0.35	10.0	78.8	17.3	
						Feed (calcd)	100.00	1.56	8.05	1.31	100.0	100.0	100.0	
B-3 Dec. 16 1985	SO_2 + aeration (prededed by graphite float) 36	45 - AF238 10 - R350 55	0	4.7	4.7	Graphite conc	6.32	1.25	3.60	1.47	5.5	2.9	7.1	
						Cl conc 2	19.79	6.00	5.16	4.88	83.3	13.1	73.6	70.2
						Cl conc 1	20.98	5.72	5.22	4.69	84.1	14.0	74.9	70.1
						Ro conc	25.26	4.83	6.14	4.03	85.6	19.8	77.5	65.8
						Ro tail	68.42	0.19	8.84	0.29	8.9	77.3	15.4	
						Feed (calcd)	100.00	1.43	7.83	1.31	100.0	100.0	100.0	
B-4 Jan 6 1986	SO_2 + aeration 36 (1)	63 - AF238 25 - R350 78	Dep 40 375 to Ro 100 to Cl	5.0	5.0	Cl conc 2*	5.13	14.26	2.91	1.36	50.5	1.9	5.4	48.6
						Cl conc 1	8.19	10.23	3.26	2.05	57.9	3.4	12.9	54.5
						Ro conc	26.91	4.56	4.08	3.52	84.8	14.1	73.0	70.7
						Ro tail	73.09	0.30	9.15	0.48	15.2	85.9	27.0	
						Feed (calcd)	100.00	1.45	7.78	1.30	100.0	100.0	100.0	

* Additional analyses: Fe 34.35%, S 41.56%, Acid insolubles 2.00%
Total of analyzed constituents, 96.44%
Calculated pyrite content, 46.6%

Table A-3 Summary of test procedure and copper flotation results for Southeast Zone No. 5 and 6 Samples

Test No. Date	Selective flotn method and grind K_{80} -µm	Collector added g/t	Depramin added g/t	Rougher Skim time - min	Copper rougher pH	Product	Copper flotation results							
							Wt %	Analysis % Cu	Analysis % Zn	Analysis % Pb	Distribution % Cu	Distribution % Zn	Distribution % Pb	Sep eff., %
B-5 Jan. 14 1986	SO_2 + aeration 36	63 - AF238 10 - R350 73	Dep 75 375 to Ro 100 to Cl	2½	5.0	Cl conc 3	4.84	16.24	6.52	1.98	53.0	3.9	7.2	49.1
						Cl conc 2	8.14	11.67	6.21	2.15	64.0	6.2	13.1	57.8
						Cl conc 1	13.45	7.78	5.45	2.96	70.5	9.0	29.9	61.5
						Ro conc	27.56	4.56	4.46	3.66	84.7	15.1	75.6	69.6
						Ro tail	72.44	0.31	9.55	0.45	15.3	84.9	24.4	
						Feed (calcd)	100.00	1.48	8.15	1.33	100.0	100.0	100.0	
B-6 Jan. 16 1986	High lime + NaCN (0.25 g/t) + aeration *	108 - AF238 20 - R350 128	Dep 75 500 to Ro	2½	11.3	Ro conc	26.57	5.79	11.87	2.85	85.6	39.4	58.4	46.2
						Ro tail	73.43	0.35	6.59	0.74	14.4	60.6	41.6	
						Feed (calcd)	100.00	1.80	7.99	1.30	100.0	100.0	100.0	
B-7 Jan. 28 1986	SO_2 + aeration *	63 - AF238 10 - R350 73	Dep "C" 375 to Ro 100 to Cl	2½	4.8	Cl conc 3	5.37	13.00	8.20	8.00	48.8	5.8	31.8	43.0
						Cl conc 2	6.72	11.20	7.76	7.39	52.6	6.8	36.8	45.8
						Cl conc 1	11.04	8.13	6.44	6.35	62.7	9.3	51.9	53.4
						Ro conc	20.66	5.80	5.38	5.07	83.7	14.5	77.6	69.2
						Ro tail	79.34	0.29	8.26	0.38	16.3	85.5	22.4	
						Feed (calcd)	100.00	1.43	7.66	1.35	100.0	100.0	100.0	
B-8 Jan. 29 1986	SO_2 + aeration *	63 - AF238 10 - R350 73	Dep XP-5 375 to Ro	2½	4.8	Cl conc 2	7.21	13.88	7.20	5.44	69.1	6.6	29.1	62.5
						Cl conc 1	10.09	10.40	6.77	5.03	72.5	8.7	37.6	63.8
						Ro conc	23.56	5.13	5.21	4.39	83.5	15.6	76.8	67.9
						Ro tail	76.44	0.31	8.67	0.41	16.5	84.4	23.2	
						Feed (calcd)	100.00	1.45	7.85	1.35	100.0	100.0	100.0	

* Primary grinding time increased from 60 to 75 minutes - fineness of grind not determined.

Table A-3 Summary of test procedure and zinc flotation results for Southeast Zone No. 5 and 6 Samples

Test No. Date	Selective flotn method and grind K_{80} -µm	Collector added g/t	Depramin added g/t	Rougher Skim time - min	Copper rougher pH	Product	Copper flotation results							
							Wt %	Analysis % Cu	Analysis % Zn	Analysis % Pb	Distribution % Cu	Distribution % Zn	Distribution % Pb	Sep eff., %
C-1 Dec. 12 1985	SO_2 + aeration 36	45 - AF238 10 - R350 55	0	3½	5.1	Cl conc 2	15.99	13.20	3.80	2.36	84.4	17.1	63.4	67.3
						Cl conc 1	20.40	10.70	3.47	1.96	87.3	19.9	67.3	67.4
						Ro conc	39.32	6.01	3.42	1.31	94.4	37.8	86.7	56.6
						Ro tail	60.68	0.23	3.65	0.13	5.6	62.2	13.3	
						Feed (calcd)	100.00	2.50	3.56	0.60	100.0	100.0	100.0	
C-2 Jan. 30 1986	SO_2 + aeration 36	45 - AF238 10 - R350 55	Dep "C" 200 to Ro	3	4.9	Cl conc 2	8.97	21.30	1.42	0.49	74.4	3.8	7.5	70.6
						Cl conc 1	17.90	12.07	1.64	0.84	84.2	8.7	25.8	75.5
						Ro conc	32.06	7.53	1.50	1.50	94.0	25.3	81.8	68.7
						Ro tail	67.94	0.23	3.70	0.16	6.0	74.7	18.2	
						Feed (calcd)	100.00	2.57	3.37	0.59	100.0	100.0	100.0	
C-3 Jan. 31 1986	SO_2 + aeration 36	45 - AF238 10 - R350 55	Dep XP-5 200 to Ro	3	4.9	Cl conc 2	9.67	21.60	1.72	0.72	79.6	4.7	11.4	74.9
						Cl conc 1	14.99	14.98	1.82	0.97	85.6	7.7	23.7	77.9
						Ro conc	29.41	8.39	2.61	1.73	94.1	21.8	83.0	72.3
						Ro tail	70.59	0.22	3.91	0.13	5.9	78.2	17.0	
						Feed (calcd)	100.00	2.62	3.53	0.61	100.0	100.0	100.0	
C-4 Feb. 5 1986	SO_2 + aeration 36	45 - AF238 10 - R350 55	**	3	4.7	Cl conc 2	15.99	13.48	4.20	2.00	86.5	19.3	53.3	67.2
						Cl conc 1	25.65	8.84	3.57	1.64	91.0	26.3	70.0	64.7
						Ro conc	34.24	6.95	3.68	1.50	95.5	36.1	85.8	59.4
						Ro tail	65.76	0.17	3.38	0.13	4.5	63.9	14.2	
						Feed (calcd)	100.00	2.49	3.48	0.60	100.0	100.0	100.0	

* Grinding time increased from 60 min (Test B-1 to B-5) to 75 min - K_{80} not determined
** Added 50 g/t humic acid and 1500 g/t KCl

Table A-4 Summary of test procedure and zinc flotation results for Southeast Zone No. 5 and 6 Samples

Test No.	Cu selective floth method	Graphite depressant g/t	Reagents added, g/t			Rougher Skim time - min	Product	Zinc flotation results						
									Analysis %			Distribution %		
			$CuSO_4$	R350	NaAF			Wt %	Cu	Zn	Pb	Cu	Zn	Pb
B-1	High lime + 50 g/t NaCN - conditioned in cell	none	1000	0.02	52	3	Zn cl conc	14.91	0.73	45.60	3.76	32.1	95.4	59.5
							Zn ro conc	21.23	0.89	32.82	4.44	55.8	97.8	82.2
							Zn ro tail	78.77	0.19	0.20	0.26	44.2	2.2	17.8
							Feed (calcd)	100.00	0.34	7.13	1.15	100.0	100.0	100.0
B-2	SO_2 + aeration	none	1000	-	130	3	Zn cl conc	11.17	0.34	50.41	0.46	17.9	94.1	16.6
							Zn ro conc	15.28	0.45	38.05	0.58	32.3	97.2	28.7
							Zn ro tail	84.72	0.17	0.20	0.26	67.7	2.8	71.3
							Feed (calcd)	100.00	0.21	5.98	0.31	100.0	100.0	100.0
B-3	SO_2 + aeration	none	1000	-	130	3	Zn cl conc	15.97	0.21	48.00	0.31	21.0	86.7	16.8
							Zn ro conc	27.47	0.25	30.22	0.36	37.2	93.9	33.6
							Zn ro tail	72.53	0.16	0.74	0.27	62.8	6.1	66.4
							Feed (calcd)	100.00	0.18	8.84	0.29	100.0	100.0	100.0
B-4	SO_2 + aeration	Dep 40 375	1000	15	117	2	Zn cl conc 2	13.73	0.31	55.70	0.56	14.2	83.6	16.1
							Zn cl conc 1	15.11	0.42	53.56	0.67	21.1	88.5	21.2
							Zn ro conc	19.69	0.55	43.08	0.84	36.0	92.7	34.6
							Zn ro tail	80.31	0.24	0.83	0.39	64.0	7.3	65.4
							Feed (calcd)	100.00	0.30	9.15	0.48	100.0	100.0	100.0
B-5	SO_2 + aeration	Dep 75 375	1000	15	117	2	Zn cl conc 2	14.03	0.29	59.86	0.36	13.0	88.0	11.3
							Zn cl conc 1	15.38	0.37	56.00	0.44	18.2	90.2	15.1
							Zn ro conc	19.59	0.53	45.70	0.60	33.2	93.8	26.3
							Zn ro tail	80.41	0.26	0.74	0.41	66.8	6.2	73.7
							Feed (calcd)	100.00	0.31	9.55	0.45	100.0	100.0	100.0

Table A-4 Summary of test procedure and zinc flotation results for Southeast Zone No. 5 and 6 Samples

Test No.	Cu selective floth method	Graphite depressant g/t	Reagents added, g/t			Rougher Skim time - min	Product	Zinc flotation results						
									Analysis %			Distribution %		
			$CuSO_4$	R350	NaAF			Wt %	Cu	Zn	Pb	Cu	Zn	Pb
B-6	High lime + 125 g/t NaCN + aeration	Dep 75 500	1000	15	117	2	Zn cl conc 2	13.38	0.84	42.70	2.88	31.9	86.6	52.2
							Zn cl conc 1	16.01	0.92	37.34	2.74	41.8	90.7	59.5
							Zn ro conc	26.53	0.83	23.64	2.06	62.5	95.1	74.1
							Zn ro tail	73.47	0.18	0.44	0.26	37.5	4.9	25.9
							Feed (calcd)	100.00	0.35	6.60	0.74	100.0	100.0	100.0
B-7	SO_2 + aeration	Dep "C" 375	2000	15	117	2	Zn cl conc 2	14.41	0.40	50.40	0.43	19.6	87.9	16.2
							Zn cl conc 1	15.54	0.47	47.89	0.51	24.8	90.1	20.8
							Zn ro conc	20.87	0.54	37.11	0.58	38.2	93.8	31.7
							Zn ro tail	79.13	0.23	0.65	0.33	61.8	6.2	68.3
							Feed (calcd)	100.00	0.29	8.26	0.38	100.0	100.0	100.0
B-8	SO_2 + aeration	Dep XP-5 375	2000	45	91	2½	Zn ro conc	21.07	0.55	38.41	0.67	37.0	93.4	34.5
							Zn ro tail	78.93	0.25	0.73	0.34	63.0	6.6	65.5
							Feed (calcd)	100.00	0.31	8.67	0.41	100.0	100.0	100.0

Table A-4 Summary of test procedure and zinc flotation results for Southeast Zone No. 5 and 6 Samples

Test No.	Cu selective floth method	Graphite depressant g/t	Reagents added, g/t			Rougher Skim time - min	Product	Zinc flotation results						
									Analysis %			Distribution %		
			$CuSO_4$	R350	NaAF			Wt %	Cu	Zn	Pb	Cu	Zn	Pb
C-1	SO_2 + aeration	none	1000	-	104	3	Zn cl conc	6.14	0.21	52.80	0.15	5.6	89.0	7.0
							Zn ro conc	11.26	0.38	31.17	0.22	18.7	96.4	18.9
							Zn ro tail	88.74	0.21	0.15	0.12	81.3	3.6	81.1
							Feed (calcd)	100.00	0.23	3.64	0.13	100.0	100.0	100.0
C-2	SO_2 + aeration	Dep "C" 200	1000	10	91	1½	Zn cl conc 2	6.80	0.39	49.60	0.28	11.6	91.0	12.1
							Zn cl conc 1	8.01	0.43	42.60	0.29	15.1	92.3	14.8
							Zn ro conc	10.81	0.46	32.23	0.30	21.8	94.0	20.6
							Zn ro tail	89.19	0.20	0.25	0.14	78.2	6.0	79.4
							Feed (calcd)	100.00	0.23	3.71	0.16	100.0	100.0	100.0
C-3	SO_2 + aeration	Dep XP-5 200	2000	10	91	1½	Zn cl conc	7.38	0.39	48.20	0.28	13.1	91.1	14.0
							Zn ro conc	11.22	0.45	32.84	0.29	23.0	94.3	22.0
							Zn ro tail	88.78	0.19	0.25	0.13	77.0	5.7	78.0
							Feed (calcd)	100.00	0.22	3.91	0.15	100.0	100.0	100.0
C-4	SO_2 + aeration	Humic acid 50 KCl 1500	1000	5	117	2½	Zn cl conc	6.83	0.18	45.70	0.19	7.2	92.2	10.0
							Zn ro conc	11.96	0.26	26.97	0.20	18.1	95.3	18.5
							Zn ro tail	88.04	0.16	0.18	0.12	81.9	4.7	81.5
							Feed (calcd)	100.00	0.17	3.38	0.13	100.0	100.0	100.0

Table A-5 Summary of test procedure and copper cleaner flotation results for Southeast Zone No. 5 Sample

Test No.	Selective flotn method	Reagents added to cleaners, g/t				Product	Copper flotation results							
		Cl No.	Depressant	pH	Collector		Wt %	Analysis %			Distribution %			Cu/Zn Sep eff., %
								Cu	Zn	Pb	Cu	Zn	Pb	
B-1	High lime + NaCN conditioned in cell	1	0	11.05	AF238-36	Cl conc 1	58.57	6.86	12.86	1.59	83.9	73.9	57.6	10.0
						Ro conc	100.00	4.79	10.22	1.62	100.0	100.0	10.0	
B-2	SO_2 + aeration	1	SO_2 + heat (88°C)	5.0	AF238-18 R350-10	Cl conc 1	63.44	5.78	3.63	1.57	90.7	46.7	32.0	44.0
						Ro conc	100.00	4.05	4.93	3.12	100.0	100.0	100.0	
B-3	SO_2 + aeration preceded by graphite float	1	0	5.1	AF238-18	Cl conc 2	78.30	6.00	5.16	4.88	97.3	66.2	95.0	31.1
		2	0	5.2	R350-10	Cl conc 1	83.06	5.72	5.22	4.69	98.2	70.7	96.6	27.5
						Ro conc	100.00	4.83	6.14	4.03	100.0	100.0	100.0	
B-4	SO_2 + aeration + 375 g/t Dep 40	1	Lime Dep 40-100	11.2	0	Cl conc 2	19.06	14.26	2.91	1.36	59.6	13.5	7.4	46.1
						Cl conc 1	30.43	10.23	3.26	2.05	68.3	24.1	17.7	44.2
		2	0	11.0	0	Ro conc	100.00	4.56	4.08	3.52	100.0	100.0	100.0	
B-5	SO_2 + aeration + 375 g/t Dep 75	1	Lime Dep 75-100	11.7	R350-10	Cl conc 3	17.56	16.24	6.52	1.98	62.6	25.8	9.5	36.8
						Cl conc 2	29.54	11.67	6.21	2.15	75.6	41.1	17.3	34.5
		2	0		0	Cl conc 1	48.80	7.78	5.45	2.96	83.2	59.6	39.6	23.6
		3	0		0	Ro conc	100.00	4.56	4.46	3.66	100.0	100.0	100.0	
B-7	SO_2 + aeration + 375 g/t Dep C	1	Lime Dep C-100	11.6	R350-25	Cl conc 3	25.99	13.00	8.20	8.00	58.3	40.0	41.0	18.3
						Cl conc 2	32.53	11.20	7.76	7.39	62.8	46.9	47.4	15.9
		2	0		0	Cl conc 1	53.44	8.13	6.44	6.35	74.9	64.1	66.9	10.8
		3	0		0	Ro conc	100.00	5.80	5.38	5.07	100.0	100.0	100.0	
B-8	SO_2 + aeration + 375 g/t Dep XP-5	1	Lime	11.5	R350-15	Cl conc 2	30.60	13.88	7.20	5.44	82.8	42.3	37.9	40.5
		2	0	11.2		Cl conc 1	42.83	10.40	6.77	5.03	86.8	55.8	49.0	31.0
						Ro conc	100.00	5.13	5.21	4.39	100.0	100.0	100.0	